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BRITISH FOSSILS

BY JOSEPH W. WILLIAMS

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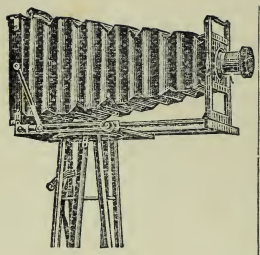

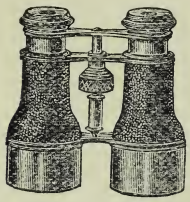

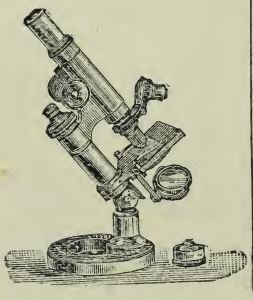

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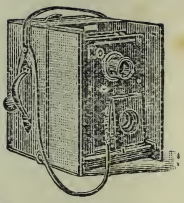

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Fig. 1.—IDEAL LANDSCAPE OF LIASSIC TIME. [*Frontispiece.*

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BRITISH FOSSILS,

AND

WHERE TO SEEK THEM.

An Introduction to the Study of Past Life.

BY

JOSEPH W. WILLIAMS,

Author of "The Shell-Collector's Handbook for the Field"; "Land and Fresh-water Shells"; "A List of all the Described Species and Varieties of British Land and Fresh-water Shells for Labelling, Reference, or Exchanging," etc.

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TO MY PARENTS,
WHOSE COMPANIONSHIP AND
HELP IN MY SCIENTIFIC WORK, AND
WHOSE SYMPATHY LIGHTENS THE CARES OF
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PREFACE.

In writing a small book like this one on Past Life in the British Isles, as shown by a study of the fossils imbedded in our own rocks, the chief difficulty has arisen out of the vast amount of monographic literature which exists on this subject. I hope, however, that I have picked out the most salient facts in the science which it is necessary that the mind of the young collector should thoroughly grasp about each formation. An elementary knowledge of physical geography, zoology, and botany will do much to help him along the road, and it would be as well that he acquire this knowledge at the outset; such knowledge as is found in Geikie's "Elementary Lessons in Physical Geography," Nicholson's "Elementary Text-book of Zoology," and Oliver's "Elementary Lessons in Botany." So dependent is the study of fossils upon a knowledge of these three sciences, that the best palæontologist is that man who has the best knowledge of them. With work in the field and reading at home, the student will find that the subject he has chosen is a most healthful and a most intellectual one. It is *the one* subject which will render him careful and cautious in the work he does,—the best attributes

of a scientific man. He will find to his astonishment unmistakable evidence that

> "Where rolls the deep, there grew the tree ;
> O Earth, what changes hast thou seen !
> There where the long street roars, hath been
> The silence of the central sea."

He will find that the life which exists to-day has been evolved through the long ages of time from pre-existing forms by a quiet slow change, "without violence, without fiction, without miracles" ; he will learn, with much more, that the stony rocks with the "life" imbedded in them, "are not eternal, but the daughters of Time." The author's indebtedness must be especially acknowledged to the works and writings of Lyell, Seeley, Nicholson, Owen, Ramsay, Brown, Jukes, Woodward, Penning, Geikie, Etheridge, Prestwich, and Jukes-Browne.

J. W. W.

MITTON, STOURPORT,
WORCESTERSHIRE.

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BRITISH FOSSILS

CHAPTER I.

INTRODUCTORY.

THE study of Palæontology (from the Greek words, *palaios*, "ancient"; *ontos*, "being"; and *logos*; "a discourse"), or the study of fossils, like its sister science, Geology, dates its real birth from no distant period. It is true that fossils were known to those who were curiously inclined in the time of the Renaissance, and even before then, but they were always designated "*Freaks of Nature*," and no one knew their real import. Indeed, so much was this a fact, that a fossil salamander which had been found in Switzerland was, not two hundred years ago, looked upon as the remains of a child which had perished in the Noachian Deluge. It remained for Buffon, a great French naturalist, to direct the attention of scientific men to these "Freaks of Nature," in his celebrated "Epoques de la Nature." He promulgated the doctrine that they were to be regarded as remains of animals and plants which had once lived upon our earth, but had long become extinct; a teaching not entirely unopposed, for Voltaire, who though he had "no wish to embroil himself with Monsieur Buffon about shells," yet in his cynical way said that the pilgrims returning from Rome had thrown those shells on the Alps and Apennines, which Buffon rightly regarded as the remains of animals which had lived their existence and died to appear no more. The greatest impulse, however, to the study of fossils was no doubt given by Baron Cuvier, when he published his work on "Ossements Fossiles." Cuvier found some bones in the plaster-quarries of Montmartre, at Paris, and from these he

made restorations or pictures of the animals they belonged to, which were remarkably accurate in almost every detail. He thus describes his method of work. "In my work on fossil bones I propose to ascertain to what animals the osseous fragments belong; it is seeking to traverse a road on which we have as yet ventured only a few steps. An antiquary of a new kind, it seemed to me necessary to learn both to restore these monuments of past revolutions, and to decipher their meaning. I had to gather, and bring together in their primitive order, the fragments of which they are composed; to reconstruct the ancient beings to which these fragments belonged; to reproduce them in their proportions and with their characteristics; to compare them, finally, with others now living on the surface of the globe; an art at present little known, and which supposes a science scarcely touched upon as yet, namely, that of the laws which preside over the coexistence of the forms of the several parts in organized beings. I must, then, prepare myself for these researches by others, still more extended, upon existing animals. A general review of actual creation could alone give a character of demonstration to my account of these ancient inhabitants of the world; but it ought, at the same time, to give me a great collection of laws, and of relations not less demonstrable, thus forming a body of new laws to which the whole animal kingdom could not fail to find itself subject."

And later, in the same book, he adds: "When the sight of a few bones inspired me, more than twenty years ago, with the idea of applying the general laws of comparative anatomy to the reconstruction and determination of fossil species—when I began to perceive that these species were not quite perfectly represented by those of our own days which resembled them the most—I no longer doubted that I trod upon a soil filled with spoils more extraordinary than any I had yet seen, and that I was destined to bring to light entire races unknown to the present world, and which had been buried for incalculable ages at great depths in the earth.

"I had not yet given any attention to the published notices of these bones by naturalists who made no pretensions to the recognition of their species. To M. Vaurin, however, I owe the first intimation of the existence of these bones, with which the gypsum-quarries swarm. Some specimens which he brought me one day struck me with astonishment. I learned,

with all the interest the discovery could inspire me with, that this industrious and zealous collector had already furnished some of them to other collectors. Received by these amateurs with politeness, I found in their collections much to confirm my hopes and heighten my curiosity. From that time I searched in all the quarries with great care for other bones, offering such reward to workmen as might awaken their attention. I soon got together more than had ever been previously collected, and after a few years I had nothing to desire in the shape of materials. But it was otherwise with their arrangement, and with the reconstruction of the skeleton, which could alone lead to any just idea of the species.

"From the first moment of discovery I perceived that, in these remains, the species were numerous. Soon afterwards I saw that they belonged to many genera, and that the species of the different genera were nearly the same size, so that size was likely rather to hinder than to aid me. Mine was the case of a man to whom had been given at random the mutilated and imperfect remains of some hundreds of skeletons, belonging to twenty sorts of animals. It was necessary that each bone should find itself alongside that to which it ought to be connected. It was almost like a small resurrection, and I had not at my disposal the all-powerful trumpet; but I had the immutable laws prescribed to living beings as my guide, and at the voice of the anatomist each bone and each part of a bone took its place. I have not expressions with which to describe the pleasure I experienced in finding that, as soon as I discovered the character of a bone, all the consequences of the character, more or less foreseen, developed themselves in succession. The feet were found conformable to what the teeth announced; the bones of the legs, of the thighs, all those which ought to reunite these two extreme parts, were found to agree as I expected; in a word, each species was reproduced, so to speak, from only one of its elements." Many since have followed in the footsteps of Baron Cuvier; but in this country, perhaps, the palm must be given to Sir Richard Owen.

Fossils (from the Latin *fossilis*, "dug up") are generally defined as organic remains of animals or plants buried in the earth by an agency other than that of man. Their study is of interest to the zoologist and botanist alike, for beside bringing him into connection with many interesting problems of distri-

bution, they teach him facts concerning the various forms of life which lived on the earth in past time, and thus render him better fitted for grasping the immensity of life which surrounds him on this earth to-day. The father of English geology, William Smith, has said about fossils, that they "are to the naturalist as coins to the antiquary; they are the antiquities of the earth, and very distinctly show its gradual regular formation, with the various changes of inhabitants in the watery element." Some of the fossils—the majority of them—are very distinct, not only in species or genus, but in family, from the animals and plants existing at the present time; but a good palæontologist (who, as we have hinted in the preface, is also a good zoologist and a good botanist) can tell by them the physical conditions of the earth at the period of their lives, and can also learn from a study of them whether the strata in which they are found were deposited in lake or estuary or sea. In the more recent strata fossils are found more or less resembling species to-day living on the earth, some of the Mollusca indeed not being distinct from species with which we are perfectly familiar, while as we go deeper and deeper to the older strata do we find fossils more and more unlike these, until we reach the Azoic rocks, in which we find very little (or no) practical evidence of any life at all. There has been, is to-day, and probably will be for all time, a progressive succession of life. Every different kind of stratum has its own distinct fossils, and the older the stratum is, the more primitive are its fossils. This will be readily seen in the following chapters.

Let us now consider the various ways and means by which the animals and plants have come down to us in the shape of fossils. Every student who has read even the most elementary treatise on geology, knows that it is only in those rocks which have been deposited by water—the stratified rocks—that fossils occur, and that they are not to be found in those other kinds of rocks which have been formed or altered by the agency of fire,—the igneous and metamorphic rocks. It is no wonder, then, that the majority of fossils belong to the fresh-water and pelagic (sea) fauna and flora. For it would be all but a chance occurrence for terrestrial animals to become fossilized in stratified deposits. They, however, now and again occur, and an explanation is to be sought in the assumption that they were drowned in rivers and then carried to the lake or sea in whose bed their remains were found. And this explanation is

borne out by the fact that they are never found whole; limb has to be jointed to limb, and bone to bone, before the palæontologist can give his dictum as to what species it belongs, or can form us a picture of the general appearance the animal had when alive. Rather than in stratified rocks, it would be in the earth of old caves like Brixham Cave and Kent's Cavern, near Torquay, that we should search for their remains and the remains of earlier man. And, as will be seen shortly, the soft-bodied animals, such as sea-anemones and jelly fishes, cannot have been preserved, owing to the very nature of their bodies, it is indeed no wonder that the geological record is incomplete. In Mr. Penning's "Field Geology,"—a book I recommend all those intending real, honest work to procure and very carefully read—Mr. Jukes-Browne gives a table which shows at a glance the relative abundance of the fossils belonging to each great group of the animal kingdom This table is the following:—

REVIEW OF ANIMAL KINGDOM.

Vertebrata.

Mammalia—occur rarely, except in recent fluviatile deposits, and then generally in the shape of separate bones and teeth.

Aves—from their aërial existence, are still rarer as fossils, bones seldom occurring; but their footprints and even impressions of their feathers are known.

Reptilia.—Remains of all recent and extinct orders are tolerably abundant, except the *Ophidia* and *Lacertilia;* their bones, teeth, scutes, and in some cases their eggs and coprolites, being found.

Amphibia—are represented in certain formations by their bones and teeth, as well as their tracks and footprints.

Pisces.—The bones, teeth, and scales of fishes are common in almost every formation, from the Silurian upwards.

Invertebrata.

Mollusca.—Remains of all those classes possessing internal or external shells are very abundant; the *Tunicates*, being soft-bodied, are alone unrepresented.

Annulosa - Of *Insects*, the skins, limbs, and wings are occasionally found; of *Myriapoda* and *Arachnida* remains are very

rare; of *Crustacea* the limbs and carapaces are frequently found.

The *Annelids* are only known by the shells of *Tubicola*, and by the tracks and burrows of other orders.

Annuloida.—Echinoderms are frequent fossils, leaving remains of their tests, stems, arms, or spines.

Cœlenterata.—The *Actinozoa* present abundant remains of their hard skeletons or corals; but the *Hydrozoa*, being mostly soft-bodied, have left few traces. *Graptolites* are the chief exception.

Protozoa—are chiefly represented by the spicules of Sponges and the minute tests of Foraminifera.

Apart from the fact that soft-bodied animals could not be preserved, if it be true—and it is generally believed—that all fossiliferous strata were formed during subsidence, then here is another and very cogent reason for believing in the imperfection of the geological record. Charles Darwin, in his memorable and epoch-making "Origin of Species," thus clearly and succinctly explained how all this may have come about. "During periods of elevation the area of the land and of the adjoining shoal parts of the sea will be increased, and new stations will often be formed—all circumstances favourable, as previously explained, for the formation of new varieties and species; but during such periods there will generally be a blank in the geological record. On the other hand during subsidence, the inhabited area and number of inhabitants will decrease (excepting on the shores of a continent when first broken up into an archipelago), and consequently during subsidence, though there will be much extinction, few new varieties or species will be formed; and it is during these very periods of subsidence that the deposits which are richest in fossils have been accumulated." And, again, a few pages later: "If, then, there be some degree of truth in these remarks, we have no right to expect to find in our geological formations an infinite number of those fine transitional forms, which on our theory have connected all the past and present species of the same group into one long and branching chain of life. We ought only to look for a few links, and such assuredly we do find." But this is not all. There is plenty of evidence to show us that many strata have been destroyed, for nowhere is there to be found a complete succession of strata. And if these strata have been destroyed,

it is a necessary corollary that the fossils imbedded in them have been destroyed also.

However, even the ways in which animals and plants have been preserved as fossils, not counting the other adverse circumstances mentioned, are not adequate enough to hand down to us specimens of all the forms of life which have existed on our globe. We must consider these ways in some little detail as they directly bear upon the subject of our little book. They are four in number. One is by replacement of matter, when the fossil is termed a *pseudomorph;* another by internal casts; another by external impressions, and yet another by the animal

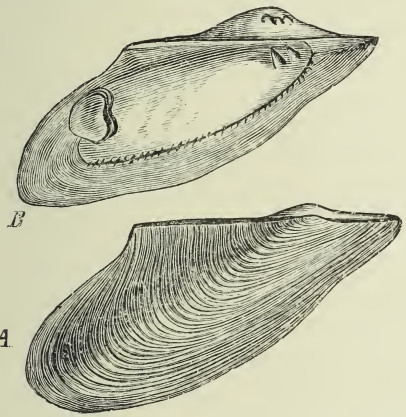

FIG. 2.—A, Fossil Bivalve Shell (*Gervillia*). B, "Cast" of the interior of the same, the actual shell having disappeared.

or plant—or portions of the animal or plant—being preserved to present time in an unchanged condition.

The first of these is by far the most common and the one generally found to be the case with the oldest fossils, such as corals, sponges, and shells. Water percolating through the strata dissolves away, by virtue of the carbonic acid gas it holds in solution, the carbonate of lime entering into their structure, and at the same time replaces it in an exact method by the precipitation of some other kind of mineral matter which it also holds in solution—generally this is calcite or silica—and which it has obtained from the strata above or around. Other minerals than these two we have just mentioned may,

however, form the replacing material, such as siderite, glauconite, marcasite, hæmatite, limonite, and pyrites. Here we have a case of true petrifaction. A very familiar example is silicified wood, in which an identical process occurs. This form of fossilization is often simulated by what may be termed false petrifaction or incrustation, when the organism becomes surrounded by a crust of carbonate of lime or peroxide of iron, but does not undergo any displacement.

The second and the third forms of fossil-making may be considered together. The interior of the shell or any hollow body becomes filled with clay or other such plastic material, forming a "cast," which faithfully reproduces the internal configuration, so much so indeed that the shape of the teeth, muscular impressions and pallial line of a bivalve may be preserved. On the other hand, the external appearance of the shell is often found taken as an impression on the surrounding rock, so that by means of an artificial cast in plaster of Paris, we may gain knowledge regarding its exact configuration; a circumstance useful indeed, since in these cases it will generally be found that the shell has been completely dissolved away, and its cast remaining in the cavity which once had formed its cerement.

Regarding the fourth way in which organisms of past time have come down to us, little need be said. It needs only to be instanced the mammoth which was found in the frozen Alaska cliffs in Escholtz Bay, and the insects found in amber. These, however, are rare instances; it is a rare thing to find organisms preserved in this way. Sometimes a kind of fossilization of bones approaching this character is found in the more recent deposits. The animal matter has been abstracted, leaving the mineral matter behind, so that the bone is found in a brittle state, which, when applied to the tongue, adheres to it. A "tip" useful to the student in diagnosing a shell-pseudomorph from one unaltered is, that the former on a blow with the hammer breaks with a distinctly angular fracture, while the latter breaks up into a series of layers or laminæ.

At the commencement we stated that a good palæontologist can tell whether the stratum under observation—according to the kind of fossils it contains—was deposited in lake, estuary, or sea. This he will know from the various species he finds in that stratum. For example, in a salt-water deposit he will expect to find shells belonging to genera allied to or identical

with those existing in our seas to-day; in an estuarine deposit he will find a preponderance of forms belonging to the genera *Melania*, *Auricula*, *Nerita*, *Cerithium*, *Cyrena*, *Melanopsis*, and *Scrobicularia;* a fresh-water one he will know by the presence of forms belonging to the genera *Linmæa*, *Physa*, *Planorbis*, *Valvata*, *Neritina*, *Ancylus*, *Unio*, *Anodonta*, and *Sphærium*, with, perhaps, one or two land-forms as *Clausilia*, *Cyclostoma*, *Helix*, *Bulimus*, and *Pupa;** and a shallow-water deposit by the existence of fossils in it belonging to the genera *Cardium*, *Littorina*, *Mytilus*, *Nassa*, *Pholas*, *Pecten*, *Solen*, *Tapes*, *Patella*, *Murex*, *Conus*, *Mitra*, and *Purpura*.

Then it would be as well, before introducing himself any further into the study of fossils, that the young student should learn what are known as Pictet's Palæontological Laws. They were first given nearly forty years ago by Pictet, a French palæontologist, and are as follows:—

"1. All species have had a limited geological duration.

"2. The contemporary species of a geological fauna in any one locality in most cases appeared simultaneously, and disappeared in the same manner.

"3. The differences between living and extinct faunas are in proportion to the geological antiquity of the extinct faunas.

"4. The diversity of animal organisation has increased with the duration of geological time.

"5. The highest types of life have a comparatively recent origin.

"6. The order of appearance on the earth of different types of life often recalls the phases of embryological development.

"7. The existence of a type on the earth is uninterrupted from its first appearance to its extinction.

"8. The ancient distribution of life shows that the distribution of temperature has changed.

"9. The geographical distribution of species found in the strata was more extended than the range of species of existing faunas.

"10. Fossil animals were constructed on the same plan as existing animals, and their lives manifested the same physiological functions."

These laws need no explanation, for they explain themselves.

* For the distinctive characteristics of these genera, see the author's little book on "Land and Fresh-water Shells" in this series.

Seen in the light of present-day science they may in reality be regarded as expressions of common sense.

A few words in conclusion, before considering British fossils in some detail, as to the way in which geologists have divided up "geological time." Geologists call strata by different names, according to the kinds of fossils they contain. Some fossils are abundant—these are known as the dermoid types; they are the remains of animals which in the time allotted to them lived in a very persistent fashion, devouring and exterminating other species, which are called the asthenoid types, and which are found in the rocks in a less abundance, and show evidence of having dwindled out of life. For example, if we may be allowed the illustration, man is a dermoid type to-day; he is persistent in his life, and has contributed not a little to the extermination of many species, as instance the Moas, the Dodo, the Soltaire, the Garefowl, the Labrador Duck, the Great Auk, and the Crested Parrot, all of which may be regarded as asthenoid types of the present era of life. To come nearer home, in our own country we may instance the Bustard, Crane, Spoonbill, and Capercailzie.

Geologists divide "geological time" into four distinct epochs —the Archean Epoch, the Palæozoic Epoch, the Mesozoic Epoch, and the Cainozoic Epoch. Of the first of these—the Archean Epoch—we shall say little in this volume, since no "life" is to be found in its rocks. Probably, however, "life" in its primal forms did exist, and the theoretical division of it into an Azoic (no life) and an Eozoic (dawn of life) Age seems warrantable. The Palæozoic Epoch is the period of the most ancient fossils as at present known to us, and preceded the Mesozoic; it includes the Cambrian and Silurian Age or Age of Invertebrates, the Devonian Age or Age of Fishes, and the Carboniferous Age or Age of Coal Plants. The Mesozoic, a long epoch, preceded the Cainozoic and succeeded the Palæozoic. Its range of time was from the end of the Permian Period or, which is the same thing, the commencement of the Triassic to the end of the Cretaceous Period. The Cainozoic commenced with the end of the Mesozoic, and includes three periods, as seen in the following table. Sometimes the Quaternary Age is reckoned as one of these periods, which then make four, but it will in this book be considered apart by itself as the Quaternary Epoch or Age of Man. Tabulating these we have,—

1. Laurentian Period (generally considered Archean).

Palæozoic Epoch.
2. Cambrian Period.
3. Silurian Period.
4. Devonian Period.
5. Carboniferous Period.
6. Permian Period.

Mesozoic Epoch.
7. Triassic Period.
8. Jurassic Period.
9. Cretaceous Period.

Cainozoic Epoch.
10. Eocene Period.
11. Oligocene Period.
12. Miocene Period.
13. Pliocene Period.

14. Post-Pliocene or Quaternary Period (in this book considered as a distinct epoch).

It will now be our duty to discuss the characteristic fossils of these several periods under their respective epochs. And having mastered this chapter, and the one to follow on collecting, let the student go a-field, for in studying nature the only way is to take her at first hand,* if he wishes to become a good, real, and honest student. Let him go out with hammer and chisel in hand to the rocks in his own district; a little acquaintance with them will show him more wonders than he thought. But remembering that "of things good and beautiful, the gods give nothing to men without great toil," it has been my aim in this book to give him the experience and knowledge which has only been wrought by others with hard toil, and in this way making, I hope, his burden a little lighter than has been that of those who have gone before him.

* Agassiz once very truthfully said, "Many study nature in the house, but when they go out of doors cannot find her."

CHAPTER II.

THE LIFE OF THE PRIMARY OR PALÆOZOIC EPOCH.

A LARGE Foraminifer, *Eozoon Canadense*, has been described from the Laurentian rocks (Archæan time) of North America, but the organic nature of this supposed fossil has been more than doubted. If it be of organic origin, then it is the oldest form of life known to have existed on the globe. But we shall not stay to discuss this question (as it does not concern a work on British fossils), but shall pass directly to our subject, taking the various periods in the order laid down in the table at the end of the last chapter. But it would be as well to mention, for the information of the student, that the Laurentian rocks are best developed in the north-west of Scotland, where they constitute nearly the whole of the Outer Hebrides, and the west part of Sutherland and Ross. Here they were first described by Sir Roderick Murchison, who called them "Fundamental or Lewisian Gneiss"; they have a definite strike from N.N.W. to S.S.E., and are composed of such materials as hornblendic gneiss, mica schist, actinolite schist, and hornblendic schist, while, especially in their lower portions, veins of pegmatite (due probably to excessive metamorphism) are a characteristic feature. They are also found as isolated patches in Pembroke, Carnarvon, and Anglesey, and they enter into the constitution of the Shropshire Wrekin, Malvern Hills, and the Lizard Peninsula, besides being found at Charnwood Forest, and as a huge granite mass in County Donegal in Ireland. They, however, contain no evidences of life, and therefore a mere mention of them is sufficient in this book. Resting unconformably upon them will be found in some localities rocks belonging to the Cambrian Period.

THE CAMBRIAN PERIOD.—The rocks of this period are of great interest to us, since they contain the first indubitable records of the past life of the globe. They are divided into

Lower and Upper Cambrian, and these again split up as follows:—

Lower { Harlech and Longmynd Series.
Menevian Series.

Upper { Lingula Flags.
Tremadoc Slates.

The Harlech and Longmynd Series.—These are the oldest known fossiliferous beds in Britain. You will find them best developed at St. David's in South Wales, and in the Longmynd Hills in Shropshire. In this last-mentioned locality they are probably 23,000 feet thick. For a long time they were thought to be devoid of fossils, but the recent researches of Dr. Hicks have brought to light the fact that they are by no means so barren as was once considered. In the red shales at Castell, to the east of Ramsey Sound, have been found the Brachiopods, *Lingulella ferruginea* and *L. primæva*, with *Leperditia cambrensis* and two species of *Discina*, while between Port Clais Harbour and Caerbuddy, in flaggy yellowish-grey sandstones, large Trilobites, such as *Plutonia Sedgwickii* and *Paradoxides Harknessi*, have been found associated with much smaller ones, belonging to the genera *Agnostus* and *Microdiscus*, and sponges belonging to the Hexactinellid group, as *Protospongia major* and *P. fenestrata*. In rocks, belonging probably to the same age, at Carrick Macreilly in Wicklow and at Bray Head near Dublin curious fossils, named *Oldhamia antiqua* and *O. radiata*, have been found, concerning the nature of which much difference of opinion exists. Some authorities, such as Goppert, refer them to the seaweeds; but Professors Kinahan and Forbes think them related to the Sertularians. The rocks of this series consist of conglomerates, flags, sandstones, and slates. The oldest known British fossil is perhaps *Arenicolites uricomiensis*, found in the quartzite beds of the Shropshire Wrekin; a worm.

The Menevian Series.—There is an advance on the number of species found in this series to those found in the Harlech and Longmynd group. Twenty more species are found. These rocks are a series of beds above the Harlech group at St. David's, and consist of sandstones, shales, flags, grey grits, and dark-blue slates; here they attain a thickness of 600 feet. The first Echinoderm, *Protocystites menevensis*, occurs in this series. Other than this there are the sponges found in the preceding series, with the addition of *P. flabellata* and three

gigantic Trilobites, viz. *Paradoxides Davidis*, *P. Hicksii*, and *P. aurora*. Species of crustacea besides Paradoxides belonging to the genera *Agnostus* (7), *Conocoryphe* (7), *Leperditia* (4), *Anopolenus* (3), *Holocephalina* (2), *Carausia* (1), *Arionellus* (1), *Microdiscus* (1), and *Erinnys* (1), are also present, the last four genera being characteristic of the series. The Mollusca are represented by four genera and six species of Brachiopods, of which *Orthis Hicksii* is worthy of special mention, and by six species of Pteropods belonging to the genera *Theca*, *Stenotheca*, and *Cyrtotheca*, viz. *T. corrugata*, *T. menevensis*, *T. stiletto*, *T. penultima*, *S. cornucopia*, and *C. hamula*. The earliest known Entomostracon (*Entomis*) occurs in these rocks. Some of the fossils are common to both the Harlech and Longmynd series and the Lingula Flags.

The Lingula Flags, so named on account of the vast numbers of *Lingulella Davisii* found in them, are found developed at St. David's, Maentwrog, Ffestiniog, Dolgelly, Borth, Llanberis, Trawsfynydd, Carnedd Ffiliast, and Marchllyn-Mawr in Wales. At Ffestiniog *Lingulella Davisii*, *Bellerophon cambrensis*, *Conocoryphe bucephala*, and *Olenus micurus* may be found; at Malvern in the black shales overlying the Hollybush sandstone in the Valley of the White-leaved Oak, *Olenus bisulcatus*, *O. pauper*, *O. humilis*, *O. scarabæoides*, *Agnostus M'Coyi*, *A. princeps*, and *Conocoryphe malvernensis;* the Dolgelly Trilobites are *Olenus scarabæoides*, *Agnostus princeps*, *A. obtusus*, *A. trisectus*, *Sphærophthalmus* (*Olenus*) *alatus*, *S.* (*Olenus*) *humilis*, *Conocoryphe Williamsonii*, *C. longispina*, and *C. abdita*. Good places for fossil collectors occur on the flanks of Cader Idris, near Dolmelynllyn, Dolgelly, and Criccieth. *Olenus truncatus* is one of the commonest fossils. *Olenus cataractes* may be found in profusion in the valley between Caen-y-coed and Taffarn-helig, and in the Waterfall Valley near Maentwrog. In what are known as the *Dictyonema* shales in the Valley of the White-leaved Oak near Malvern, underlying the black shales above-mentioned, may be found a large number of a Polyzoon, *Dictyonema sociale*. The earliest known Heteropods (*Bellerophon*) and Phyllopods (*Hymenocaris*) are found in the Lingula Flags. In some places these flags attain a thickness of 5,000 feet. They consist of sandstones, blue, black, and grey flags, and slates.

The Tremadoc Slates, so called by Professor Sedgwick from Tremadoc in Carnarvonshire, where they are found as dark

grey slates about 1,000 feet thick. At Ramsay Island and Whitesand Bay in Pembrokeshire, near Portmadoc, Llanerch, Garth, Penclogwyn, Borthwood, Penmorfa, Dudreath, and

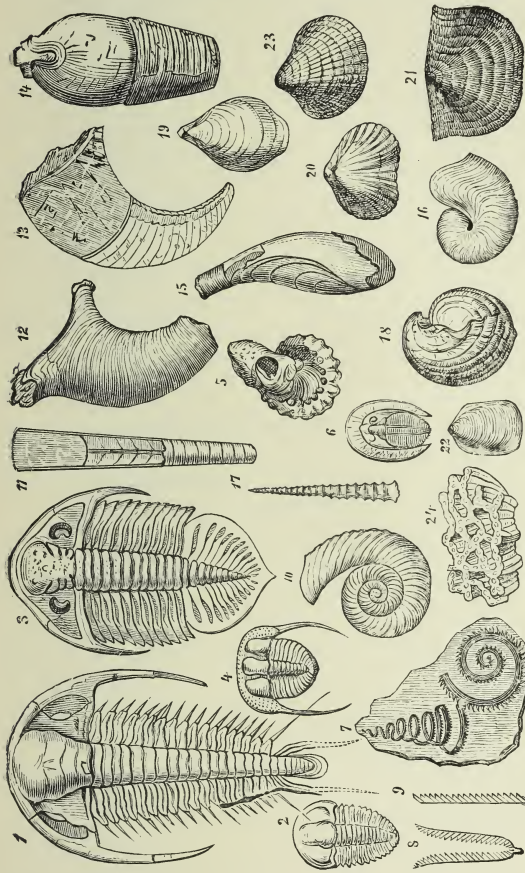

Fig. 3.—Characteristic Fossils of the Silurian System and Part of the Cambrian.
1, *Paradoxides bohemicus*; 2, *Ellipsocephalus Hoffi*; 3, *Dalmanites Hausmanni*; 4, *Trinucleus ornatus*; 5, *Placops cephalotes*; 6, *Harpes ventalosus*; 7, *Graptolithus turriculatus and G. convolutus*; 8, *Didymograptus (Graptolithus) bifidus*; 9, *Monograptus (Graptolithus) Römeri*; 10, *Lituites*; 11, *Orthoceras*; 12, *Phragmoceras*; 13, *Cyrtoceras*; 14, *Gomphoceras*; 15, *Asoceras*; 16, *Bellerophon bilobatus*; 17, *Tentaculites ornatus*; 18, *Pentamerus Knightii*; 19, *Terebratula meionica*; 20, *Rhynchonella Wilsoni*; 21, *Leptæna depressa*; 22, *Lingulella (Lingula) Davisii*; 23, *Cardiola interrupta*; 24, *Halisites (Catenepora) catenularia*.

Tyn-y-llan they also occur. At Ramsay Island the first crinoid and Asteroid—*Dendocrinus cambrensis* and *Palæasterina ramseyensis*—are found, and also the first Lamelli-

branchs, consisting of species belonging to the genera *Davidia*, *Glyptarca*, *Palæarca*, *Ctenodonta*, and *Modiolopsis*. At the other places mentioned occur crustacea of many shapes and forms. In the lower strata (Lower Tremadoc) *Niobe menapiensis*, *N. Homfrayi*, *Angelina Sedgwickii*, *Psilocephalus innotatus*, and *Asaphus affinis* are the most characteristic; in the upper strata (Upper Tremadoc) *Olenus impar*, *Lingulocaris lingulocomes*, *Angelina Sedgwickii*, *Ceratiocaris latus*, and *Conocoryphe olenoides*. The first known cephalopods in Britain—*Cyrtoceras præcox* and *Orthoceras sericeum*—are found in these rocks.

The Silurian Period.—The name of Silurian was first given to the rocks of this period by Sir Roderick Murchison, because they are most typically developed in South Wales, the home of the ancient tribe of the Silures. They rest conformably on the Cambrian beds, and consist of conglomerates, limestone beds, shales, sandstones, flagstones, and slates. The average thickness of the Silurian strata is approximately 18,550 feet. They submit of the following divisions, each of which must be considered separately:—

Lower Silurian
1. Arenig, or Stiper Stone Group.
2. Llandeilo Group.
3. Bala and Caradoc Group.
4. Lower Llandovery Group.

Upper Silurian
5. Upper Llandovery Group.
6. Wenlock Group.
7. Ludlow Group.

The Arenig, or Stiper Stone Group, consisting of shales, flags, sandstones, and darkish-coloured slates, is found well developed, as the name implies, in the Arenig mountain in North Wales, where it rests conformably on the Tremadoc slates, and underlies the Llandeilo flags. Good places for working this group are near Portmadoc, at Ty-o-bry, and Tan-yr-Allt; the cliffs of Whitesand Bay and along the coast between Porth Melgan and Abereiddy Bay, and at Borthen-mawr and in Llanvirn quarry. This group forms part of the mountain chains of Cader Idris, Arenig, the Ffestiniog mountains, and Arran Mowddy. Crustacea are present as *Agnostus hirundo*, *A. Morei*, *Phacops Nicholsoni*, *Asaphus affinis*, *Caryocaris Marrii*, *Orgygia peltata*, *O. bullina*, *O. scutatrix*, and various species of *Amphyx*, *Æglina*, *Trinucleus*, *Calymene* and *Barrandia*; Lamp-shells are there, as *Lingulella Davisii*, *L. attenuata*,

Orthis alata, *O. calligramma*, *O. lenticularis*, *O. striatula*, *O. remota*, and *Siphontreta micula;* Lamellibranchs, as *Palœarca amygdalus*, *Redonia anglica*, and *Ribieria complanata*. At Llavirn Gastropods may be found; these are a form referable to the genus *Ophileta*, and *Pleurotomaria llanvirnensis*. A few "Sea-Butterflies" or Pteropods are found belonging to the genera *Theca* and *Conularia*, while in what is known as the Corndon area in Shropshire, Cuttle-fish occur belonging to the species *Orthoceras encrinale* and *O. Avelinii*. During the time in which this group was being deposited, volcanic action was in full force, as evinced by the quantity of lava which is found interstratified in these rocks; and especially is this shown by the fact that volcanic materials make up the greatest bulk of Cader Idris and the other Welsh mountains that have been just previously mentioned.

The Llandeilo Group, so called by Sir Robert Murchison, who first described them as found at Llandeilo in Carmarthenshire, consists of chalky and clayey flags, shales and sandstones. Besides visiting Llandeilo for fossils belonging to this group, the collector must also visit Builth in Radnorshire, and Abereiddy Bay near St. David's; the rocks at Musclewick Bay, Llandewi Velfrey, Lampeter Velfrey, Haverford-West, and especially Narberth, will also repay a visit. The Irish collector may visit the cliffs of Ballymoney and the rocks round Slieve Bernagh in County Clare; the Moffat shales in Scotland also belong to this group. A Protozoon has been found named *Ischadites antiquus*. The Actinozoa are represented by *Favosites fibrosus*, *Halysites catenulatus*, and *Monticulipora favulosa;* the Echinoderms by *Echinosphærites granulatus*, *Actinocrinus Wynnei*, *Palœasterina Kinahani*, and *Glyptocrinus basalis;* Trilobites are very abundant, *Cheirurus Sedgwickii*, *Asaphus tyrannus*, *Trinucleus Lloydii*, *T. favus*, *T. concentricus*, *Calymene cambrensis*, and *Barrandia Cordai* being the most characteristic; the Lamellibranchs are characterized by *Palœarca amygdalus*, *Ctenodonta varicosa*, *Modiolopsis expansa*, and *M. inflata;* the Pteropods by three species, two of which occur at St. David's viz., *Theca cæreesiensis* and *T. reversa*, and the Cuttle-fish by *Endoceras eoum* and *Orthoceras Avelani* (?); the Lamp-shells are frequent, thirty-four species being recorded, of which five new genera—*Leptæna*, *Crania*, *Rhynchonella*, *Strophomena*, and *Acrotreta*—appear for the first time. The characteristic fossils of the beds of this group are *Trinucleus fimbriatus*, *Orgia*

Buchii, *Didymograpsus Murchisoni*, *Diplograpsus foliaceus*, *Ampyx nudus*, *Lingula attenuata*, and *Rastrites peregrinus*.

The Caradoc and Bala Group.—The beds belonging to this group are to be found at Caer Caradoc, near Church Stretton in Shropshire, and round Bala in Merionethshire; at the former locality they consist of grey and yellowish sandstones, and at the latter of grey and dark slates, sandstones and grits; the Bala beds can be well seen between Bettws-y-coed, Bettws-gwerfulgoch, and Dinas-Mowddy, in Wales. Fossils belonging to no less than 614 different species, and 179 genera have been obtained from this group. Between Long Sleddale and Broughton Mills in Furness, a series of beds of a calcareous nature, termed "Coniston Limestones," occur, which probably belong to the same age; as also do the beds of Portraine in County Dublin, and of the Chair of Kildare. The Actinozoa are represented by 40 species belonging to 20 genera—the Crustacea belong to the genera *Asaphus*, *Acidaspis*, *Agnostus*, *Calymene*, *Phacops*, *Lichas*, *Remopleurides*, *Amphyx*, *Homalonatus*, *Illænus*, and *Cheirurus;* the Bivalves are represented by the genera *Ctenodonta*, *Palæarca*, *Modiolopsis*, *Pterinæa*, *Orthonota*, and *Ambonychia;* the Gastropods by *Patella*, *Holopella*, *Cyclonema*, *Murchisonia*, *Raphistoma*, *Euomphalus*, and *Pleurotomaria;* and the Cuttle-fish by *Orthoceras*, *Lituites*, *Trocholites*, and *Cyrtoceras*. Star-fish belonging to the genera *Stenaster* and *Palæaster* occur, and there are no less than 23 species of cystideans.

The Lower Llandovery Group is well developed at the town of Llandovery, where the beds consist of grey grits with bands of conglomerate. The most characteristic fossils are *Murchisonia angulata*, *Meristella crassa*, *M. angustifrons* and *Nidulites favus*.

The Upper Llandovery Group is well exposed at Cherbury, Norbury, and Church Stretton in Shropshire; at May Hill in Gloucestershire (for this reason they are sometimes called the *May Hill Sandstones*); at the lower Lickey Hills in Worcestershire, and on the west flank of the Malvern Hills; at Marloes Bay in Pembrokeshire; and at Llandovery and Presteign in South Wales; and at Woolhope and Tortworth. They form the true base of the Upper Silurian division, and are composed of yellowish and brown sandstones, with beds of conglomerate and impure limestone. The fossils are apt to "weather," and so leave casts. At Malvern *Stricklandinia lens* is common; also *Ctenodonta Eastnori* and *Lingula crumena*. One *supposed*

"plant," *Fucoides gracilis*, is known from this group, which is probably an Annelid or the burrowing track of some mollusc; at Malvern is found a species of burrowing sponge, *Cliona gracilis*, similar to the *Cliona* of our own seas; the Actinozoa are represented by the genera *Halysites*, *Lindströmia*, *Omphyma*, *Propora*, *Pinnacopora*, *Streptelasma*, *Labechia*, *Plasmopora*, *Ptychophyllum*, *Favosites*, *Heliolites*, *Petraia*, *Syringopora*, and *Palæocyclus;* the first Echinoid, *Palæchinus Phillipsiæ*, is found in the Pembrokeshire beds; the Annelids *Tentaculites ornatus*, and *Cornulites serpularia* are fairly common, and so are the Trilobites *Illænus Thomsoni*, *Phacops Stokesii*, *Proëtus Stokesii*, *Calymene Blumenbachii*, and *Encrinurus punctatus;* sixty-five species of Lamp-shells have been found, of which *Stricklandinia lirata*, *S. lens*, *Orthis calligramma*, *O. elegantula*, *Pentamerus oblongus*, *Leptæna transversalis*, *Atrypa reticularis*, *A. hemispherica*, and *Lingula parallela* may be mentioned. Mytiloid Lamellibranchs belonging to the genera *Modiolopsis*, *Orthonota*, and *Mytilus* are found. Nine species of Gastropods have been found in the Worcestershire beds; while Heteropods, as *Bellerophon dilatatus*, *B. lobatus* and *B. carinatus*, and Cephalopods belonging to the genera *Orthoceras*, *Cyrtoceras*, *Lituities*, *Actinoceras*, and *Phragmoceras* are also present in these beds.

The Wenlock Group includes more fossils than any other group of the Upper Silurian. No less than 530 species, belonging to 168 genera, have been described. We may divide the group into four sub-groups, viz.,—

(1) Tarrannon Shales.
(2) Woolhope Limestone.
(3) Wenlock Shales.
(4) Wenlock Limestone.

The Tarrannon Shales are found near Builth in Radnorshire, near Llandovery, and along the southern flanks of the Cyrny-brain mountains north of Llangollen. They consist of fine, smooth, greyish or bluish slates, and were termed the "paste-rock" by Sedgwick. The fossils are few. Crustacea are present, such as *Calymene Blumenbachii*, *Acidapsis Barrandii*, *Phacops caudatus* and *Beyrichia klædeni;* the Lamp-shells are represented by fifteen species belonging to ten genera; and the Gastropoda by *Acroculia haliotis*.

The Woolhope Limestone and shale, composed of greyish shales, is well exposed in the valley of Woolhope in Herefordshire, at Walsall and Great Bar in Staffordshire, and on the western flank of the Malvern Hills. At May Hill in Gloucestershire, and at Old Radnor, Presteign, and Nash Scar in Radnorshire, these beds are also well-developed. The commonest fossils are *Pterinea Sowerbyii*, *Cardiola striata*, and *Mytilus mytilimeris* among the Lamellibranchs; *Phacops caudatus*, *Homalonotus delphinocephalus*, and *Illænus* (*Bumastus*) *Barriensis* among Trilobites, and *Orthis calligramma*, *Rhynchonella Wilsoni*, and *R. borealis* among the Brachiopoda.

The commonest Cuttle-fish are *Lituites cornu-arietes*, *Orthoceras conicum*, and *Actinoceras baccatus;* the commonest Gastropod is *Euomphalus sculptus.*

The Wenlock Shales are well seen on the banks of the Severn near Ironbridge and Coalbrook Dale, and along the flanks of Wenlock Edge. The fossils are so exceedingly small, that in a cartload of the shale from Buildwas, Messrs. Davidson and Maw state that there were found 4,300 specimens of a single species of Brachiopod, *Orthis biloba*, which is the commonest fossil. *Phacops caudatus*, *P. longicaudatus*, *Calymene Blumenbachii*, *C. tuberculosa*, *Encrinurus punctatus*, and *E. variolaris* are the commonest Trilobites.

The Wenlock Limestone is a sub-group consisting of beds of concretionary limestone, found near Dudley at the Wren's Nest and Castle Hill, near Coalbrook Dale, Aymestry, Woolhope, the west flank of the Malvern Hills, at Wenlock Edge, Benthall Edge and Gliddon Hill. The "Dudley Locust," *Calymene Blumenbachii* (a Trilobite), is abundant at Dudley; Lamellibranchs belonging to the genera *Pterinea*, *Cardiola* and *Cucullella* are abundant in this sub-group; so are the Trilobites *Phacops Stokesii*, *P. caudatus*, *Illænus* (*Bumastus*) *Barriensis*, *Homalonotus delphinocephalus*, *Cheirurus bimucronatus*, *Encrinurus punctatus* and *E. variolaris. Bellerophon wenlockensis* is a common Heteropod, and *Rhynchonella borealis* a very common Brachiopod. The merostomatous Crustaceans first appear in this sub-group; they are represented by *Eurypterus punctatus*, *Hemiaspis horridus*, and *Pterygotus problematicus.* Corals and Crinoids are especially abundant.

The Ludlow Group of rocks consists of shales, with now and then a band of limestone in the middle of them. The group admits of the following division into three sub-groups:—

(1) Lower Ludlow Rocks.
(2) Aymestry Limestone.
(3) Upper Ludlow Rocks.

The Lower Ludlow Rocks will be found developed at Malvern, Usk, Woolhope, Vinnal Hill, Dormington, Ornibury and Mocktree. Leintwardine, in Shropshire, is a very abundant locality; and here the remains of the first fish, *Scaphaspis Ludensis*, have been found. Cephalopoda are numerous, especially *Orthoceras ludense*, and *O. subundulatum*, and species belonging to the genera *Lituites* and *Phragmoceras*. Trilobites begin to wane, but *Calymene Blumenbachii* may still be found, and also *Phacops caudatus* and *P. longicaudatus*. Star-fishes are fairly abundant, and these correspond to the brittle-stars of our own seas—*Protaster leptosoma*, *P. Miltoni* and *P. Sedgwickii* may be mentioned as illustrative. Most of the fossils—especially the Trilobites—will be found forming the nucleus of calcareous nodules, which are common in these rocks. Locally, the beds generally go by the name of "mudstones."

The Aymestry or *Ludlow Limestone*, found developed at Sedgely in Staffordshire, west of Wenlock Edge and in the Ludlow promontory at Aymestry, is a lens-shaped bed of limestone, generally from one to five feet thick. The most common fossil is a Brachiopod shell, *Pentamerus Knightii*, which can be found in large numbers in the beds exposed on the sides of the river Lugg at Aymestry. The other common fossils are the Brachiopods *Rhynchonella Wilsoni*, *Lingula Lewisii* and *Strophomena Euglypha*, the Lamellibranch *Pterinæa Sowerbii*, and the Heteropod *Bellerophon trilobatus*.

The Upper Ludlow Rocks are well developed between Trecastle and Llandovery, and near Ludlow. At Hales End near Malvern, Ludlow, Stoke Edith, Bradnor Hill near Kingston, Pyrton Passage, May Hill, and Huntley Hill, what is known as the Ludlow Bone Bed occurs as a brown layer two or three inches in thickness, full of fish-remains, crustacean telsons (tail-spines), and shells. The jaws of *Plectrotus pustuliformis*, *P. mirabilis*, and the skin and scutes of *Sphagodus pristodontus*, with fragments of large Pterygoti, may be found in the bone beds. Now and then the old "Dudley Locust" may be found in these rocks; but Trilobites are on the wane and represented by only a few species, such as *Encrinurus punctatus*, *Phacops Downingiæ*, and *Homalonotus Knightii*. *Murchisonia*

corallii, *Platyschisma helicites* and *Holopella obsoleta*, are the commonest Gastropods ; the Lamellibranchs are represented by *Pterinea lineata*, *P. retroflexa*, *Orthonota amygdalina* and

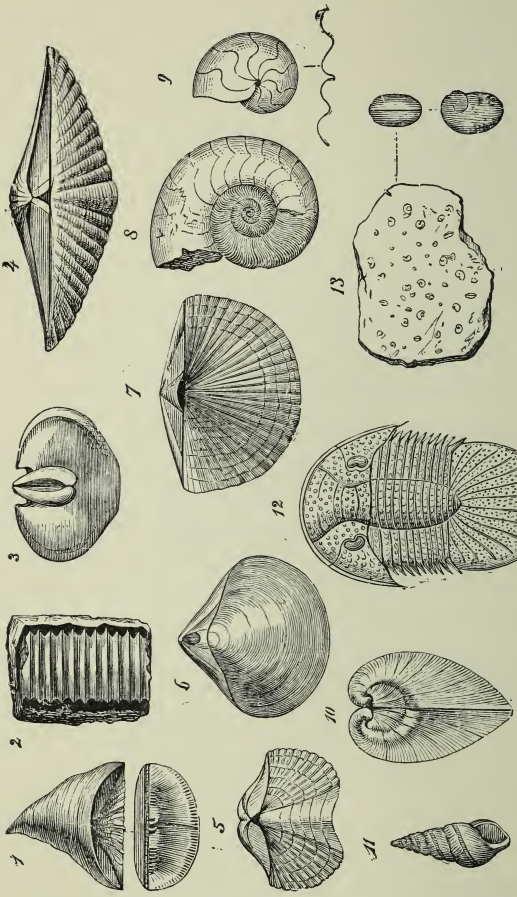

FIG. 4.—Group of Devonian Fossils.
1, *Calceola sandalina*, the so-called "Pantoffelmuschel," actually a coral ; 2, *Cyathocrinus* ; 3, *Hysterolithes vulvarius* ; 4, *Spirifer speciosus* ; 5, *Spirifer ostiolatus* ; 6, *Stringocephalus burtini* ; 7, *Orthis umbraculum* ; 8, *Clymenia undulata* ; 9, *Goniatites retrorsus* ; 10, *Megalodon cucullatus* ; 11, *Murchisonia bilineata* ; 12, *Brontes flabelliferi* ; 13, *Cypridina* (*Entomis*) *serrato-striata*.

Gonisphora cymbæformis ; the Brachiopods by *Lingula lata*, *L. minima*, *Strophomena filosa*, *Discina rugata*, *Rhynchonella Wilsoni* and *Chonetes striatella*. Some plants are found, which

are by some considered fucoids, but their real nature has not yet been positively determined. *Chondrites verisimilis*—a beautiful seaweed—is found in the Scottish beds.

The Devonian Period includes the fossils of the Old Red Sandstone formation, as well as those of the Devonian beds. These two for the sake of exactness in detail, we shall have to consider separately.

A. *The Old Red Sandstone*, known doubtless to the majority of you from Hugh Miller's graphically written book, is essentially a Scottish formation. Its fossils are of fresh-water or terrestrial origin, and thus differ materially from those of the Devonian rocks, which are of marine origin; the rocks themselves were probably deposited in lakes or inland seas com-

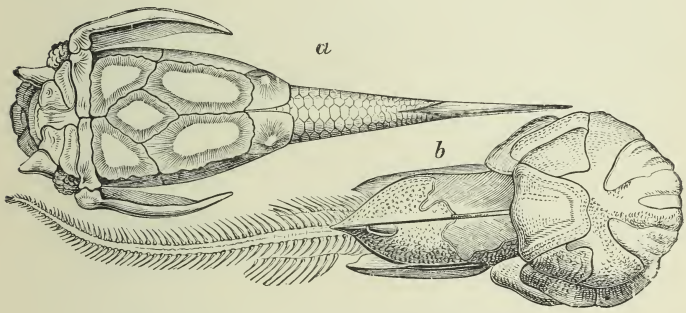

Fig. 5.—Fishes from the Old Red Sandstone of Scotland.
a, *Pterichthys cornutus* (under side); *b*, *Coccosteus decipiens* (upper side).

parable to the great lakes of North America. Though essentially, as stated, a Scottish formation, the Old Red Sandstone attains to a thickness of 10,000 feet in some parts of South Wales, and in Herefordshire, Worcestershire, and Somersetshire in England. The name "Old" is given to the formation in order to distinguish it from another formation of sandstone which overlies the coal measures, to which the name of "New Red Sandstone" has been applied. This formation admits of two subdivisions:—

(1) The Lower Old Red Sandstone.
(2) The Upper Old Red Sandstone.

Through a knowledge of "these *venerable* deposits, we obtain

some of the earliest traces of land on the surface of the globe. They bring before us portions of the Palæozoic continent, which preceded our modern Europe."

The Lower Old Red Sandstone.—Prof. Geikie, in studying the deposits of this subdivision, has been led to give "short names for the different detached basins" in which it was deposited. Thus, using his nomenclature, we have—

1. Lake Orcadie.
2. Lake Caledonia, or the Mid-Scottish Basin.
3. Lake Cheviot.
4. The Welsh Lake.
5. The Lake of Lorne.

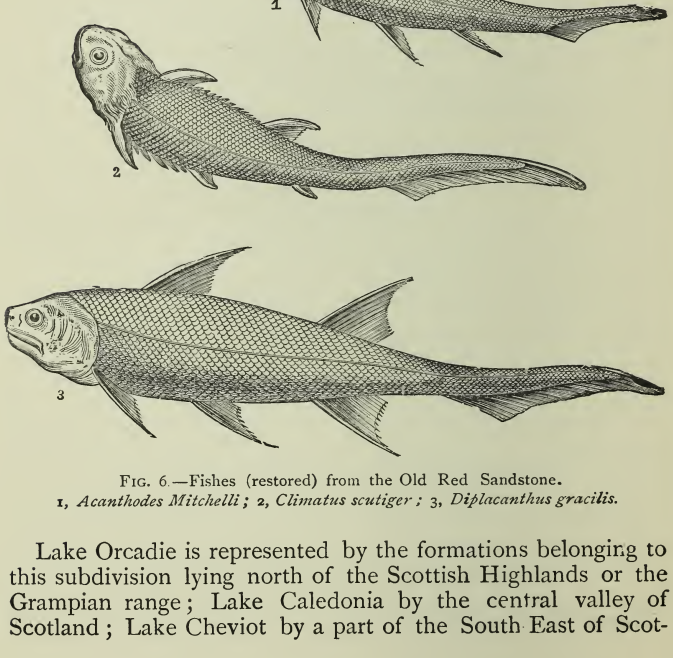

FIG. 6.—Fishes (restored) from the Old Red Sandstone.
1, *Acanthodes Mitchelli*; 2, *Climatus scutiger*; 3, *Diplacanthus gracilis.*

Lake Orcadie is represented by the formations belonging to this subdivision lying north of the Scottish Highlands or the Grampian range; Lake Caledonia by the central valley of Scotland; Lake Cheviot by a part of the South East of Scot-

land and the North of England; the Welsh Lake by the formations in South Wales; and the Lake of Lorne by "a district in the north of Argyleshire, extending from the south-east of Mull to Loch Awe, and, perhaps, northward up to the line of the Great Glen." The formation consists of various kinds of flagstones, conglomerates, and shales, with irregular-shaped calcareous nodules. Fossils are scarce; fishes are characteristic, and especially those belonging to the genera *Cephalaspis*, *Pteraspis*, *Coccosteus*, *Dipterus*, *Pterichthys*, *Asterolepsis*, and *Acanthodes* (see figs. 5 and 6). At Kilmster, fragments of a large Crustacean, probably a *Pterygotus*, may be found. The formations of Lake Orcadie have been most studied, and Prof. Geikie, in his memoir on the "Old Red Sandstone of Western Europe," occupies no less than 108 quarto pages in their consideration. As it is in this little book impossible to give even a short *résumé* of this exhaustive monographic account, the Scottish student of the rocks is advised to make a direct reference to the Professor's paper. He will find it in the 28th volume of the "Proceedings of the Royal Society of Edinburgh," for 1878, a book which can be obtained at the majority of our large public libraries. But in the event of his not being able to make a reference, the following table of the rocks at Caithness may be extracted. In it, Prof. Geikie divides the Caithness rocks into local groups. It shows "the order, thickness, and typical localities of the leading subdivisions of the Old Red Sandstones of Caithness, in descending order."

The Thurso Group is full of fish, and, doubtless, where this group occurs it would be well for the student to collect. *Osteolepsis microlepidotus* is the commonest form, but three species of each of the genera *Acanthodes*, *Cheiracanthus*, and *Diplacanthus* also occur. A very common fossil is *Glyptolepis elegans*. Plant-remains are also common, especially those of *Psilophyton robusticus*, *Caulopteris Peachii*, and *Lycopodites Milleri*. The John O'Groat's Sandstone Group contains, besides several plants, *Glyptolepis leptopterus*, *Pterichthys Dicki*, *Acanthodes Peachii*, *Tristichopteris alatus*, and an undetermined species of *Dipterus*. Few fossils are found in Lake Caledonia; the strata here show a maximum thickness of 20,000 feet. "The accumulation of so great a thickness," says Professor Geikie, "can only be explained on the supposition that the earth movements, which at first elevated the Silurian sea-floor into land, *enclosing separate basins*, continued

through subsidence to deepen those basins, until eventually enormous masses of sediment, which had accumulated *pro rata* with subsidence, had filled or gathered in them."

Subdivisions.	Strata.	Thickness in feet.	Localities where the rocks occur.
John O'Groat's Sandstone and Flagstone Group.	9. Red sandstone, with occasional bands of flagstone, thin impure limestone, and shale.	2,000	John O'Groat's House on the shore.
Huna Flagstone Group.	8. Flagstones, shales, and thin impure limestone.	1,000	Shore at Huna.
Gill's Bay Sandstone.	7. False-bedded red sandstones.	400	Gill's Bay on Pentland Firth.
Thurso or Northern Flagstone Group.	6. Dark grey and cream-coloured flagstones, grey and blue shales and thin limestones, some beds strongly bituminous. This group is more fissile, shaly, and calcareous than No. 5.	5,000	Coast-line of Caithness from Reay to Dunnet Bay, and from Brough to Gill's Bay, Stroma, and the Orkney Islands.
Wick and Lybster, or Eastern Flagstone Group.	5. Dark grey flagstones, often thick-bedded, thin shales, and limestone bands, passing into red shales and sandstones.	5,000	Coast on either side of Wick, and inland to Banniskirk.
Lower Red Sandy and Conglomerate Group.	4. Dark-red sandstones and occasional red shales and bands of fine conglomerate, passing inland into conglomerate sandstone.	2,000	Coast south and north of Berriedale Water, Sarclet, Braemore, Morven, etc.
Do.	3. Brecciated conglomerate.	300	Coast at Badbea.
Do	2. Dull chocolate-red sandstones, and sandy shales or clays.	450	Berriedale Water around Braemore.
Do.	1. Coarse basement conglomerate.	50	Berriedale Water below Braemore, and mouth of Ousedale Burn,
		16,200	

The Upper Old Red Sandstone is well developed at Dura Den in Forfarshire, and in the south and south-west portions of Ireland, where it overlies what is known to geologists as the

"Glengariff grits." In the cliffs above the railway station near Waterford, a fern known as *Palæopteris hibernica*, a mollusc *Anodon Jukesii*, and scales of *Coccosteus* and *Glyptolepsis*, have been found; and near Glengariff, at Toe Head, the first two of these fossils have also been obtained. Fossils, however, are very rare in the Upper Old Red Sandstone.

FIG. 7.—Reproduction of Devonian Plants.
A. *Fucoids* (sea-weeds); B. *Zosterites* (plant allied to the modern *Zostera*, or sea-grass); C. *Psilophyton princeps*.

B. *The Devonian Rocks.*—The term "Devonian" was first given by Murchison and Sedgwick to a group of rocks found in Devonshire and Cornwall, which had been shown to be of an age intermediate between the Silurian and Carboniferous. The fossils are of marine origin. The rocks admit of division into—

(1) Lower Devonian.
(2) Middle Devonian.
(3) Upper Devonian.

The Lower Devonian Rocks will be found at Lynton in the valley of the Lynn Brook, at Polraun, Fowey, and Polperro on the south coast of Cornwall, at Meadfoot in Torbay, and about two miles east of the railway at Warberry Hill in South Devon. In the cliffs west of Lynmouth they are well seen. The rocks consist of grey and blue slates and grits, with interstratified bands of impure limestone in which the majority of the fossils occur; at Foreland, near Lynmouth, these beds pass down into red, brown, and grey sandstones, known as the Foreland sandstones, which have not yet yielded any fossils. Scales of *Phyllolepsis* occur at Meadfoot; scales of *Scaphaspis*, *Phyllolepsis concentricus*, and *Pteraspis* at Polraun, Fowey, and Polperro; and *Homalonotus*, and *Pleurodictyum* near Warberry Hill. One species of Gastropod, *Pleurotomaria aspera*, is only found in these rocks; and only four species of Lamellibranchs, viz., *Ctenodonta Krachtæ*, *Pterinæa anisota*, *P. spinosa*, and *Aviculopecten*. One long-lived species, *Atrypa reticularis*, connects the Devonian group with the Silurian.

The Middle Devonian Rocks are full of fossils. Good sections will be found along the coast line from Combe Martin Bay to Ilfracombe, at Watermouth, Heddon's Mouth, West Challacombe, and at the Little and Great Hangman. In the limestone quarried at Ipplepen near Torquay, a large number of corals may be taken; these are chiefly *Favosites*, *Heliolites*, *Acervularia*, and *Cyathophyllum*. *Cyrtina Lemarlii*, *Athyris concentrica*, *A. lachryma*, *Pentamerus brevirostris*, *Uncites gryphus*, *Atrypa reticularis*, and *Rhynchonella acuminata* are some of the Brachiopods; Gastropods may be found as *Murchisonia bilineata*, *Euomphalus serpens*, *Porcellia Woodwardii*, and *Macrocheilus brevis;* two sponges, *Stromatopora concentrica* and *S. placenta*, are characteristic; and there are six species of Trilobites, viz., *Cheirurus articulatus*, *Bronteus flabellifer*, *Harpes macrocephalus*, *Phacops punctatus*, *P. granulatus*, and *P. latifrons*. If the young collector should visit the Continent in search of fossils, he will find many belonging to this sub-group in the Eifel, at Gerolstein and Pelm, and in the neighbourhood of Cologne, at Passrath and Bensberg.

The Upper Devonian Rocks are seen at Pickwell Down, Pilton, Baggy Point, Marwood, Dulverton, and Morte Bay. The best fossil-bearing beds are those of Pilton and Petherwin, in Cornwall. Here are found the minute Ostracod *Entomis* (*Cyprinida*) *serrato-striata*, a Lamellibranch, *Cucullæa Hardingii*,

the Trilobites *Phacops granulatus* and *P. latifrons*, and several species of Cephalopods, including the coiled forms, as *Clymenia*

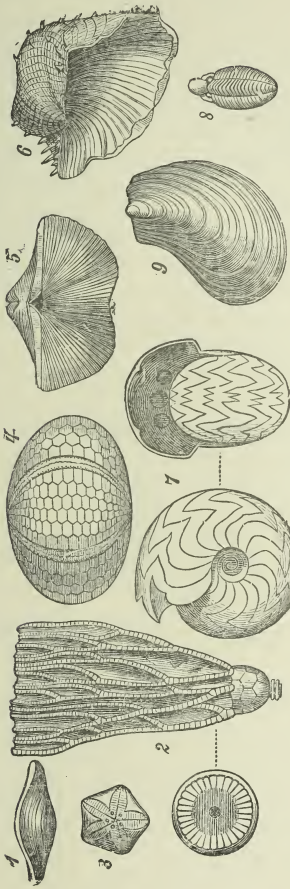

FIG. 8.—Fossils of the Carboniferous Limestone and the Culm Beds.

1, *Fusulina cylindrica*; 2, *Cyathocrinus* (the crown or "calyx" and a transverse section of the stalk); 3, *Pentatrematites floreali*s (crown from above); 4, *Palechinus gigas*; 5, *Spirifer striatus*; 6, *Productus semireticulatus*; 7, *Goniatites crenistria*; 8, *Phillipsia*; 9, *Posidonomya Becheri*.

striata, *C. undulata*, and *C. lævigata*, with Brachiopods, as *Strophomena rhomboidalis*, *Spirifera Verneuli*, *Chonetes hardrensis*, and *Productus subaculeatus*. These rocks consist of

grey and reddish sandstones and flags, grey and brown slates, and bands of impure limestone. The Pickwell Down beds, according to Mr. Ussher, do not contain any fossils.

The Carboniferous Period is sometimes called the period of gigantic vegetation. The rocks belonging to this period admit of the following division: their maximum thickness is 23,000 feet.

(1) Carboniferous Limestone.
(2) Millstone Grit.
(3) Coal Measures.

The Carboniferous Limestone, sometimes known by the name of "Mountain Limestone," consists in great part of limestone,

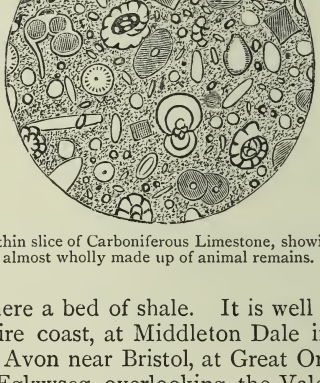

Fig. 9.—Part of a thin slice of Carboniferous Limestone, showing that the rock is almost wholly made up of animal remains.

with here and there a bed of shale. It is well shown all round the Pembrokeshire coast, at Middleton Dale in Derbyshire, in the gorge of the Avon near Bristol, at Great Orme's Head, and in the cliff of Eglwyseg overlooking the Vale of Llangollen. The formation is essentially a marine one, and so full of organic remains (see Fig. 9) as to lead one to think that it is composed of nothing else. In a small book like this, only a general knowledge of the fossils of these rocks can be given. Crinoids are especially abundant, and come out in relief on its weathered surface. The characteristic plants are *Palæopteris inæquilaterata*, *P. polymorpha*, *P. frondrosa;* the Lepidodendroids, as *Lepidodendron squamosum*, *L. Veltheimianum*, and *L. Weikianum*

FIG. 10.—*Lepidodendron Sternbergii* (restored), 40 feet high.

with *Bornia transitionis*, *Stigmaria rugosa*, and *S. ficoides*. Tubicolar Annelids and Polyzoa abound; the majority of the former belonging to the genera *Cornulites*, *Vermilia*, *Serpulites*, and *Spirorbis*, those of the latter to the genera *Diastopora*, *Glauconome*, *Vincularia*, *Polypora*, *Sulcoretepora*, and *Fenestella*. The Brachiopods chiefly belong to the genera *Productus*, *Spirifera*, and *Rhynchonella*, the Lamellibranchs to *Aviculopecten*, *Pecten* and *Pterinæa*, the Gastropods to *Euomphalus*, *Loxonema*, *Macrocheilus*, *Murchisonia*, *Pleurotomaria*, *Natica*, and *Turritella*. Forty species of Foraminifera have been described by Brady from the Carboniferous Limestone. Fishes are abundant; the most characteristic species being *Psammodus porosus*, *Orodus ramosus*, and *Pœcilodus Jonesii*.

The Millstone Grit is made up of quartzose sandstones, and, as its name implies, is generally used in the manufacture of millstones. The Welsh miners term it, "The Farewell Rock," because when they have reached it they bid good-bye to finding a seam of coal beneath it. It is almost entirely devoid of fossils, and therefore need not occupy our further attention.

The Coal Measures consist of alternating layers of different coloured sandstones and shales, fire-clays, clay-ironstones, and coal-seams. Huge ferns, club-mosses, shrubs, and trees covered the land during the formation of the coal-measures, and it is to their existence that we owe the coal which we burn in our fires to-day. Coal consists of organic matter derived from these plants by a process of decomposition, and is almost entirely composed of carbon, and compounds of carbon with hydrogen. Buried in the earth or under water, these plants have died, and their wood has suffered decomposition by the evolution of carbonic acid (CO_2) and carburetted hydrogen (CH_4), thus making the residue richer in carbon. This will be readily seen in the following table, taken from Roscoe and

	Carbon.	Hydrogen.	Oxygen and Nitrogen.
Wood	50·00	6·00	44·00
Irish Peat	60·02	5·88	34·10
Lignite from Cologne	66·96	5·25	27·76
Earthy Coal from Dax	74·20	5·89	19·90
Cannel Coal from Wigan	85·81	5·85	8·34
Newcastle Hartley	88·42	5·61	5·97
Welsh Anthracite	94·05	3·38	2·57

Schorlemmer, which shows the percentage composition of wood, peat, lignite, coal, and anthracite.

Probably the climate of the Carboniferous Period, during the deposition of the coal measures, was not unlike that of the North Island of New Zealand. There is no reason to believe in the theory advanced by Dr. Sterry Hunt, that the large growth of the ferns and club-mosses was due to their living in an atmosphere containing more carbonic acid gas than the atmosphere of the present day, for we cannot think that the physiological processes of the amphibians, which swarmed under the trees at that time, were any way different from those in a present-day amphibian. We cannot think that *they* could live in a poisonous atmosphere. The period was one of great volcanic activity.

Taking the flora of the Coal Measures first, we find a vast variety of forms. Beautiful impressions of fern-fronds are common enough in almost every coal-seam, and sometimes these have been found bearing the organs of fructification. *Odontopteris*, *Sphenopteris*, *Cyclopteris*, *Neuropteris*, *Palæopteris*, and *Alethopteris* are among the common genera. The *Calamites* were gigantic specimens of the lowly horse-tails; they, however, differ in some particulars from their modern representatives in the structure of their stems, and in their fructification. *Sphenophyllum*, and also *Annularia* and *Asterophyllites*, are, probably, only different forms of the foliage of Calamites. The Club-Mosses are represented by the *Lepidodendra* (fig. 10), which branched and rose to a height of forty or sixty feet, bearing at the extremities of their branches scaly cones (strobili), which were their fruits; these fruits have been described by palæontologists under the name of *Lepidostrobi*. The commonest trees, however, were, doubtless, the Sigillarias, for they are found in nearly every coal-seam, their stems being in the coal-seams, and their rhizomes (*Stigmariæ*) in the under-clay. They were taller trees than the Lepidodendrons; their stems were fluted longitudinally, and their fruit borne at the bases of modified leaves. The name of *Sigillaria* has been given to this genus, because the trunks are regularly ornamented by pits or scars, the points at which the leaves were attached. Other than these, stems, belonging to the genera *Araucarioxylon*, *Pinites* and *Dadoxylon*—true Conifers—have been found, but they differ from the modern Conifers in the very large size of their piths. Leaving the plants and turning to the animals,

we find Lamellibranchs not unlike our modern Unios, but they seem to have been capable of living in brackish and even salt water; the chief genera are *Anthracomya*, *Anthracosia* and *Anthracoptera*. Insects—crickets, beetles, cockroaches, white ants, and May-flies—were abundant, with Myriapods and scorpions. "White ants preyed on the timber, and converted every fallen trunk into dust; millipedes aided in the same work; May-flies and dragon-flies flitted over the stagnant pools and rivers; crickets and locusts and grasshoppers kept up that eternal chant so familiar to every one who has lived in a region haunted by them; while the croak of the huge frog-like batrachians would add variety to the sounds, which gave an earnest of the coming times to the forests which we now burn in the shape of coal." The most peculiar and interesting feature in these old Carboniferous insects, is the fact which has been elucidated by M. Ch. Brongniart, that some wings, neuropterous in character,—they had been referred to the neuropterous genus *Dictyoneura*—were attached to bodies which were decidedly orthopterous. Really, dragon-fly wings to a cockroach-like body. Some of the dragon-flies were evidently of a large size; one, a species of *Dictyoneura*, found in the Derbyshire coal-field, had an expanse of wing of perhaps fourteen or more inches. In the interior of fossil trees in the Nova Scotia Coal Measures, land-snails have been found belonging to the genera *Pupa*, *Dendropupa*, *Zonites*, *Anthracopupa* and *Dawsonella*. If the student has already made himself acquainted with a knowledge of British land-shells, such as is to be found in the author's "Land and Fresh-water Shells" in this series, he already knows the characteristics of the genera Pupa and Zonites; it will be then interesting to him to know that the Zonites is allied to a form now living in the Antilles, and the Pupa to an existing West Indian species. Passing on to the amphibian Labyrinthodonts, the "lions" of the then existing world, which probably lived on the fish and crustacea in the lagoons in which the coal was forming, we find that there existed in Britain species belonging to no less than thirteen genera; the principal genera being *Loxomma*, *Urocordylus*, *Pholiderpeton*, *Ophiderpeton*, *Anthracosaurus* and *Pteroplax*. Their length was from a few inches to as many as seven or eight feet. The family name of Labyrinthodonts has been given them owing to the peculiar structure of their teeth, which, seen in cross section, are in so many foldings and puckerings as to warrant the name on first

sight. Their skull is not unlike the crocodile's; the body was long and salamander-like, with a ventral armour of oval scales,

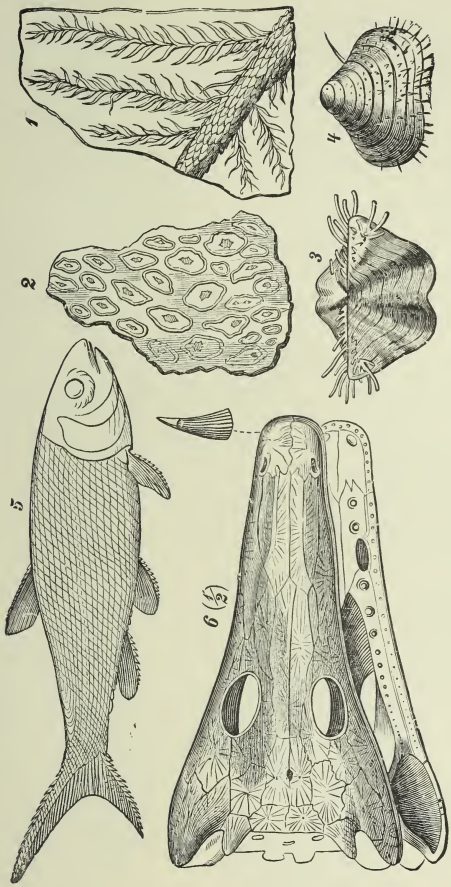

Fig. 11.—Fossils of the Permian Period.

1, *Walchia piniformis*; 2, *Psaronius asterolithus* (the "staarsten" of the German peasants), a tree-fern cut across; 3, *Productus horridus*; 4, *Strophomena excavata*; 5, *Palæoniscus freieslebeni*; 6, *Archegosaurus decheni* (the skull with tooth; half the natural size).

and the limbs were short. Spines, scales, and teeth of fishes are fairly abundant, and now and then an entire specimen. The common genera are *Mesolepis*, *Gyracanthus*, *Pleuracanthus*,

Megalichthys, *Ctenoptychius*, *Ctenodus*, *Cheirodus*, and *Strepsodus*. Footprints of an animal, provisionally named *Cheirotherium*, have been found.

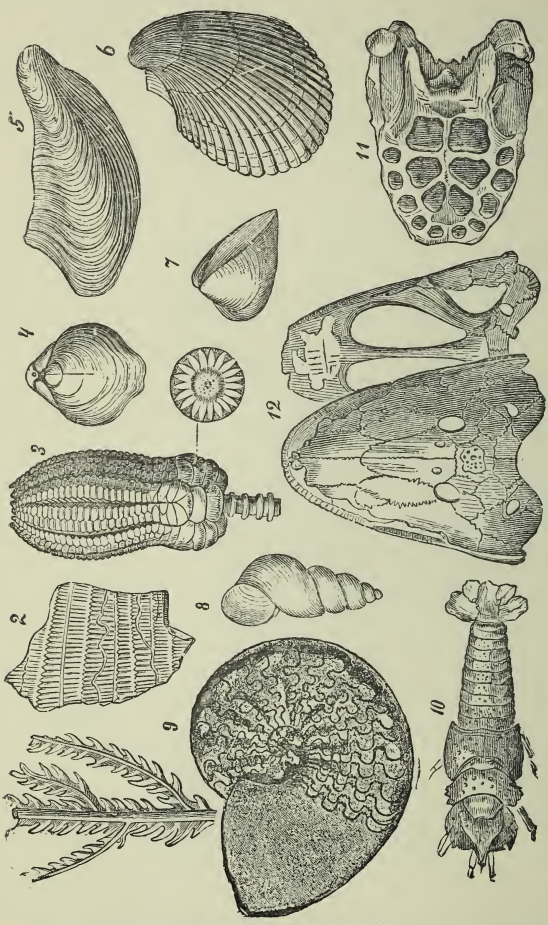

FIG. 12.—Triassic Fossils.

1, *Voltzia heterophylla*; 2, *Equisetum columnare*; 3, *Encrinus liliiformis* (calyx and section of the stalk); 4, *Terebratula* (*Waldheimia*) *vulgaris*; 5, *Gervillia socialis*; 6, *Lima striata*; 7, *Myophoria* (*Trigonia*) *cardissoides*; 8, *Melania Schlotheimii*; 9, *Ceratites nodosus*; 10, *Pemphyx Sueurii*; 11, *Placodus gigas* (under surface of the upper jaw of a saurian reptile confined to the Muschelkalk); 12, *Capitosaurus robustus* (skull) from the Keuper.

THE PERMIAN PERIOD is a transition period between Palæozoic and Mesozoic time, and on the Continent is generally called

the Dyassic Period. Between this and the Carboniferous Period, there was a physical break. The rocks are red sandstones, passing into conglomerates at one locality, and fine shales at another, with breccias of gneiss, dolomite, mica-schist, etc., derived from the older Palæozoic rocks. Along the coastline from Tynemouth to Hartlepool, at Enville in Shropshire, Collyhurst near Manchester, and in the Vale of Eden, they will be best seen, while the dolomite breccias (Magnesian Limestone) run through England, from South Shields to Nottingham. It is in this Magnesian Limestone that the chief fossils occur. *Walchia piniformis*, *Cyclopteris dilatata*, *Neuropteris Huttonia*, and *Alethopteris Göpperti* are characteristic plants. The Brachiopods are represented by *Productus horridus*, *Spirifera permiana*, and *Lingula Credneri;* the Lamellibranchs by *Gervillia antiqua*, *Lima permiana*, and *Allorisma elegans;* the Gastropods by *Turbo helicinus*, *Turbonilla Phillipsii*, and *Pleurotomaria antrina;* the fishes by *Acrolepis Sedgwickii*, *Palæoniscus elegans*, and *Cœlacanthus caudalis;* and the reptiles by *Lepidotosaurus Duffii*, *Dasyceps Bucklandi*, and *Chelichnis ambiguus*. Crustacea are not represented; Sigillarias and Lepidodendrons are on the wane, glacier action was prevalent, and perhaps there was a "Glacial Period." The Pennine range of hills, which forms the backbone of England, was "born" during this period, and probably it was about this time that the Atlantic continent, connecting Europe and America, broke up and disappeared for ever.

CHAPTER III.

THE LIFE OF THE SECONDARY OR MESOZOIC EPOCH.

THE TRIASSIC PERIOD begins the Mesozoic Epoch; the Permian Period we have just considered ends the Palæozoic Epoch. Life is beginning to get more and more like that existing on the earth at the present day. The word Triassic is an unfortunate one, as it indicates a local development of rocks which is found in Germany, but does not exist in England. The word indicates a threefold division of the rocks, and the middle division, the Muschelkalk of Germany, is absent in this country. We have thus a division in this country into—

(1) Lower Trias, or Bunter.
(2) Upper Trias, or Keuper.

The Lower Trias, or *Bunter*, *Rocks* consist of red and variegated sandstones, with pebble beds. Near Teignmouth in Devon, near the Birmingham and Sutton coal-field in Warwickshire, at Holt on the river Dee, and at Nottingham (where they exist as the pebble beds on which the castle is built), are suitable localities for their study. The fossils are few. The plants, *Albertia elliptica*, *Equisetum arenaceum* and *Æthophyllum speciosum*, and the reptiles *Placodus impressus* and *Nothosaurus Schimperi* are the most characteristic of this division.

The Upper Trias, or *Keuper*, *Rocks* are almost devoid of fossils in England, though the same formation in Germany yields a large quantity of land plants. The beds are composed of red and grey shales and marls, with white sandstones, and pass upwards into a series of red, grey, and green marls, grey limestones, and dark shales, generally known as the Rhætic, or Penarth, beds. The majority of the fossils of the Triassic Period in England are found in these beds. They are well developed at Penarth Head near Cardiff, at St. Audrey's Slip

in Somersetshire, and at Westbury in Gloucestershire; the student wishing to study these beds must visit these localities.

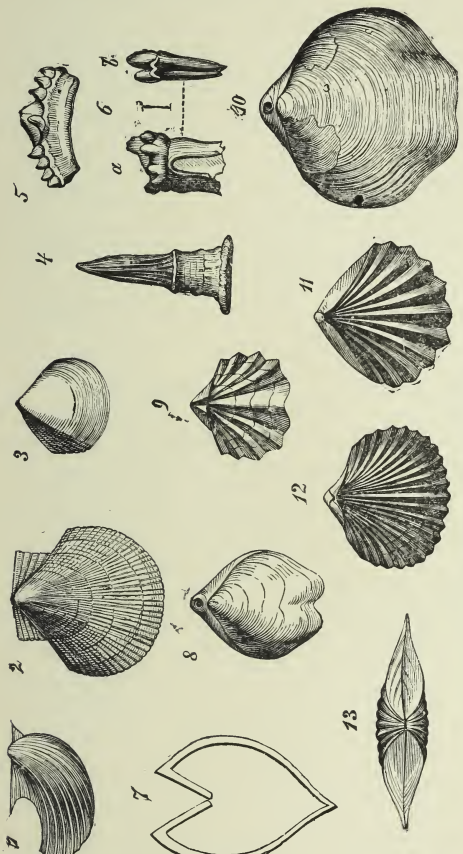

FIG. 13.—Fossils of the Rhætic Beds of the Trias.

1, *Avicula* (*Cassianella*) *contorta*; 2, *Pecten valoniensis*; 3, *Cardium rhæticum*; 4, *Saurichthys apicalis* (fish-tooth); 5, *Hybodus* (fish-tooth); 6, *Microlestes* (*Hypsiprymnopsis*) *antiquus* (back-tooth—two views, *a* and *b*, the upright line between the two showing the actual length of the molar); 7, *Cardium* (*Discorcardium*) *triquetrum* (section); 8, *Terebratula gregaria*; 9, *Spiriter Münsteri*; 10, *Spirigera oxycolpos*; 11, *Rhynchonella austriaca*; 12, *Rhynchonella fissicostata*; 13, *Rhynchonella cornigera*.

Those staying at Weston-super-Mare as a seaside resort, will find their spare time well spent in studying these beds at Uphill cutting. The most characteristic fossils are represented in fig. 13.

The commonest shells are *Avicula contorta*, *Pecten valoniensis*, *Cardium rhæticum*, and *Schizodus* (*Myophona*) *angulatus*. The earliest known mammal, *Microlestes antiquus*, which probably was allied to the banded ant-eater of Australia, has been found in these rocks, and *Ichthyosauria* and *Plesiosauria* first make their appearance. The modern mud-fishes are represented by several species of *Ceradotus;* and other fishes occur, chiefly belonging to the genera, *Acrolepis*, *Saurichthys*, *Sargodon*, and *Gyrolepis*.

The Jurassic Period, sometimes called the Oolitic Period, is the Age of Reptiles. A glimpse of the probable character of the landscape of a part of this period is shown in the frontispiece to this volume. Classifying the English rocks of the period, we have the following grouping:—

Formations or Series.	*Groups or Stages.*	*Sub-groups or Sub-stages.*
Lower or Bath Oolites. Lias.	Lower Lias.	
	Marlstone.	
	Upper Lias and Midford Sands.	
	Inferior Oolite	Lower part of Northampton Sands ("Dogger" of Yorkshire), Cheltenham beds (Pea Grit, Freestones, Inferior Oolite Marl, Gryphite Grits, Trigonia Grits).
	Fuller's Earth	Fuller's Earth.
	Great Oolite Group . .	Great or Bath Oolite with Stonefield Slate.
		Bradford Clay and Forest Marble.
		Cornbrash.
Middle or Oxford Oolites	Oxfordian . .	Oxford Clay and Kellaways Rocks.
	Corallian . .	Coral Rag and Calcareous Grit.
Upper or Portland Oolites.	Kimeridgian .	Kimeridge Clay.
	Portlandian .	Portland Sands.
		Portland Stone.
	Purbeckian .	Lower Fresh-water beds.
		Middle Marine beds.
		Upper Fresh-water beds.

We will consider each of these formations or series separately.

The Lias is a name which was first given by William Smith to

a series of rocks in Somersetshire, where, when seen in section, they appear banded, the word Lias indicating the way in which the Somersetshire quarrymen pronounce the word "layers." As seen in the previous group-table we have the—

(1) Lower Lias.
(2) Middle Lias, or Marlstone.
(3) Upper Lias.

Ammonites first occur in the *Lower Lias;* and according to the species most frequent in the several beds of this sub-group, palæontologists have divided up the beds into divisions or zones; thus we have 1. the *Zone of Ammonites planorbis;* 2. the *Zone of Ammonites angulatus;* 3. the *Zone of Ammonites Bucklandi;* 4. the *Zone of Ammonites Turneri;* 5. the *Zone of Ammonites obtusus;* 6. the *Zone of Ammonites oxynotus;* and 7. the *Zone of Ammonites raricostatus.*

(1) The Zone of *Ammonites planorbis* will be found by the collector in the coast-sections near St. Audrey's Slip and Watchet in Somersetshire, at Pinhay Bay and Lyme Regis in Dorsetshire, at Binton and Wilmcote in Warwickshire, and at the quarries about Street in Somersetshire. *Ammonites planorbis, A. Johnstoni, Ostrea liassica, Unicardium cardioides, Protocardium Philippianum,* and *Pleuromya Crowcombeia* are common fossils. At Street *Ichthyosauria* and *Plesiosauria* are not unfrequent; and species of fish belonging to the genera *Pholidophorus* and *Dapedius* can now and then be unearthed.

(2) The Zone of *Ammonites angulatus* is well shown in the Harbury cutting of the Great Western Railway near Leamington, at Bath, Lyme Regis, Brocastle, Redcar, and Sutton. The more common fossils are *Ammonites angulatus, Am. Conybeari, Gryphæa arcuata, Unicardium cardioides, Anomia striatula, Septastræa excavata, Perna infraliassica,* and *Cardinia Listeri.*

(3) The Zone of *Ammonites Bucklandi* is the zone of which our knowledge is greatest. At Redcar, Lyme Regis, and Robin Hood's Bay (between the Old Peak and Baytown), Harbury, and the Saltford cutting between Bath and Bristol on the Great Western Railway, fossils of this zone are frequent. At Robin Hood's Bay large specimens of *Ammonites Bucklandi,* with *A. semicostatus, Modiola lævis, Ostrea arcuata, Pecten textorius,* and *Monotis inæquivalvis* are common. *Pecten*

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textorius, *Ammonites Conybeari*, *A. bisulcatus*, *Lima gigantea*, *Belemnites acutus*, and *Montlivaltia Guettardi* are, among many others, to be found at Redcar. In the Saltford cutting the chief fossils are *Lima pectinoides*, *Arietites Bucklandi*, *Belemnites acutus*, *Pecten textorius*, *Pholodomya glabra*, and *Ichthyosaurus communis*.

(4) The Zone of *Ammonites Turneri* is thin and not well developed. It is exposed at Bredon and other places in the deep cuttings of the Gloucester and Birmingham Railway, and at Lyme Regis. At this last locality *Ammonites Turneri* and *Rhynchonella variabilis* are numerous, with three species of large *Ichthyosauri*, viz., *I. communis*, *I. platyodon*, and *I. intermedius*.

(5) The Zone of *Ammonites obtusus* occurs in a coast section at Lyme Regis in a well-developed condition. Here the Cephalopods, *Arietites obtusus*, *A. stellaris*, *Nautilus striatus*, and *Belemnites acutus* may be found; the fish *Lepidotus rugosus*, *Chondrosteus crassior*, *Dapedius granulatus*, and *Pachycormus heterurus*, with the reptiles *Scelidosaurus Harrisoni* and *Ichthyosaurus platyodon*, may be found.

(6) The Zone of *Ammonites oxynotus* is comparatively poor in fossils. These consist in the main of species belonging to the genera *Cardium*, *Gryphæa*, *Cardinia*, *Homomya*, and *Belemnites*. It will be found developed at Robin Hood's Bay in Yorkshire, and also at Redcar and Ayton.

(7) The Zone of *Ammonites raricostatus* is seen well developed in the railway cutting at Honeybourne in Warwickshire, at Cleeve near Cheltenham, at Marl Hill and Bredon. *Ammonites raricostatus*, *Pleurotomaria similis*, *Cardinia Listeri*, and *Hippopodium ponderosum* occur as well-marked specimens in this zone at Cleeve, Marl Hill, and Bredon.

The *Middle Lias* is divided into five zones after the manner in which the Lower Lias is divided. We have 1. the *Zone of Ammonites Jamesoni;* 2. the *Zone of Ammonites capricornus* or *ibex;* 3. the *Zone of Ammonites Henleyi;* 4. the *Zone of Ammonites margaritatus;* and 5. the *Zone of Ammonites spinatus*. The rocks of the Middle Lias are well shown at Colbourn Nab, in the cliffs at Lyme Regis, and at Down Clift near Bridport. The whole of the Yorkshire Lias, with the exception only of the lowest part, is well exposed in the cliffs at Boulby.

(1) The Zone of *Ammonites Jamesoni* is well exposed at

Fenny Compton in Warwickshire, between Boulby and Lofthouse Alum Works, and in Robin Hood's Bay in Yorkshire.

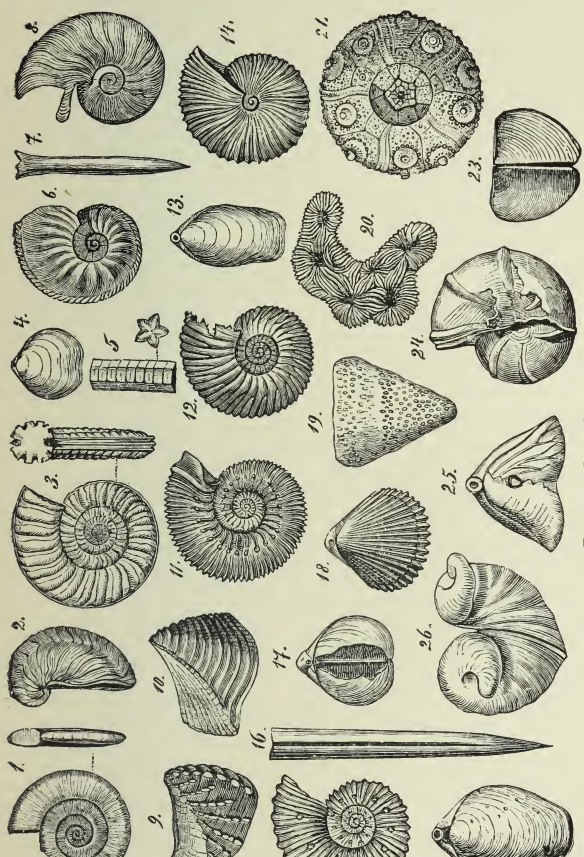

FIG. 14.—Jurassic Fossils.

1, *Ammonites planorbis*; 2, *Gryphæa arcuata*; 3, *Ammonites Bucklandi*; 4, *Terebratula nummalis*; 5, *Pentacrinus basaltiformis*; 6, *Ammonites margaritatus*; 7, *Belemnites paxillosus*; 8, *Ammonites opalinus*; 9, *Trigonia navis*; 10, *Trigonia costata*; 11, *Ammonites Humphriesianus*; 12, *Ammonites Parkinsoni*; 13, *Terebratula lagenalis*; 14, *Ammonites macrocephalus*; 15, *Ammonites ornatus*; 16, *Belemnites canaliculatus*; 17, *Terebratula impressa*; 18, *Rhynchonella lacunosa*; 19, *Spongites reticulatus*; 20, *Astrea confluens*; 21, *Cidarites coronatus*; 22, *Terebratula insignis*; 23, *Apsychus latus* (*lævis*); 24, *Ammonites tatricus*; 25, *Terebratula diphya*; 26, *Diceras arietina*.

Besides *Ammonites Jamesoni*, *A. armatum*, *A. fimbriatum*, and *Amaltheus ibex* are well-known forms of this zone.

(2) The Zone of *Ammonites capricornus* occurs at Robin

Hood's Bay, Rockcliff, Huntcliff, Colbourn Nab, and at Mickleton tunnel in Worcestershire. Ammonites and star-fish are fairly plentiful. The Ammonites include *A. capricornus* (= *A. maculatus*), *A. fimbriatus*, *A. Bechei*, and *A. defossus;* the star-fish *Ophioderma Milleri*, *O. Gaveyi*, *O. carinata*, *Uraster carinatus*, *Ludia Murchisonia*, *Tropidaster pectinatus*, and *Ophiolepis Murrayi*. Three species of Belemnites and a large number of bivalves may also be found.

(3) The Zone of *Ammonites Henleyi* is well exposed in cliff sections at Westhay Cliff, Black Ven and Golden Cap in Dorsetshire. Here occur various Belemnites, as *B. clavatus*, *B. longissimus*, and *B. elongatus;* Ammonites, as *A. Loscombi*, *A. Henleyi*, *A. Davœi*, and *A. Becheri;* Gastropods, as *Pleurotomaria similis*, *Trochus imbricatus*, and *Cryptœnia expansa*, with Lamellibranchs, represented by *Hinnites tumidus*, *Plicatula spinosa*, and *Crenatula ventricosa*.

(4) The Zone of *Ammonites margaritatus*, well developed in Yorkshire, occurs near Huntcliff, Boulby, Colbourn Nab, Staithes and Hawsker in coast-sections; in Gloucestershire at Robin Wood's Hill and Churchdown; and near Banbury in Warwickshire. The characteristic fossils are *Ammonites margaritatus*, *Cardium truncatum*, *Belemnites elongatus*, *Helicina expansa*, *Pleuromya unionides*, *Avicula inœquivalvis*, and *Mytilus hippocampus*.

(5) The zone of *Ammonites spinatus* is found near Churchdown in Gloucestershire, in the cliffs of Hawsker Bottoms, in Down Cliffs near Bridport Harbour in Dorsetshire, at Kettleness and Old Nab, and in the vale of the Eske near Whitby. *Pecten œquivalvis*, *Monotis inœquivalvis*, *Dentalium elongatum*, *Ammonites spinatus*, *A. solitarius*, *Pleuromya rostrata*, *Turbo cyclostoma*, and *Belemnites breviformis*, are characteristic fossils in the Hawsker Cliffs. Near Whitby the common fossils are *Pecten œquivalvis*, *Rhynchonella tetraœdra*, *R. lineata*, *R. capitula*, *Ostrea submargaritacea*, *Monotis cygnipes*, *Macrodon liasinus*, *Belemnites breviformis*, and *Ammonites spinatus*.

The *Upper Lias* is well seen on the coast between the Peak south of Whitby and Saltburn in Yorkshire, at Cleevecloud near Cheltenham, and Breedon Hill in Gloucestershire, near Stainby in Lincolnshire, at Gretton, Stamford, Pilton, and Manton in Rutlandshire, and in Dorsetshire at Down Cliffs and Golden Cap. As in the Middle, so in the Upper

Lias, we have five different zones represented by different species of Ammonites, viz., 1, the *Zone of Ammonites annulatus;* 2, the *Zone of Ammonites serpentinus;* 3, the *Zone of Ammonites bifrons;* 4, the *Zone of Ammonites Jurensis;* and 5, the *Zone of Ammonites opalinus.*

(1) The Zone of *Ammonites annulatus* is well exposed in the cliffs between Port Mulgrave and Brackenbury Wyke north of Whitby, between Egton and Grosmont, and along the face of the Boulby Cliffs. The chief Ammonites are *A. annulatus*, *A. semisulcatus*, and *A. concavus;* the chief Belemnites, *B. striolatus*, *B. cylindricus*, *B. breviformis*, and *B. latisulcatus;* the Lamellibranchs are represented by *Rhynchonella jurensis.*

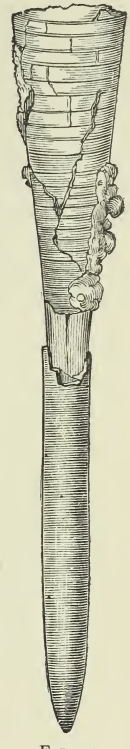

Fig. 15. *Belemnites elongatus.*

(2) The Zone of *Ammonites serpentinus* is well represented in the Upper Lias. Good places to collect are near Saltwick Nab south of Whitby, at Ilminster in Somerset, and on the tops of Churchdown Hill and other outliers of the Cotteswold range, such as the hills of Gretton, Bredon, and Alderton. Near Saltwick Nab *Inoceramus dubius* is very common; and a fish, *Gyrosteus mirabilis.* The Ammonites are *A. serpentinus*, *A. elegans*, and *A. heterophyllus;* the Belemnites are *B. dorsalis*, and *B. tubularis.* In what is known as the "Jet Rock," there are remains of fish and reptiles.

(3) The Zone of *Ammonites bifrons*, sometimes called the "*Communis*" or "*Alum Shale*," contains numerous remains of the fish-lizards, *Ichthyosauria* and *Plesiosauria;* large quantities of a shell, *Leda ovum;* and a crocodile, *Teleosaurus.* The other characteristic fossils are *Hinnites papyraceus*, *Inoceramus cinctus*, *Lingula longoviciensis*, *Ammonites elegans*, *A. Levisoni*, *A. heterophyllus*, *A. bifrons*, and *A. cornucopiæ.* Typical localities for working this zone are near Whitby, on the Banbury and Cheltenham Railway near Bloxham in Oxfordshire, and on the Santon railway cutting in Lincolnshire.

(4) The Zone of *Ammonites jurensis* is shown near Bath in

Sometsetshire, in Gloucestershire in the valleys of Nailsworth and Brimscombe, and in Dorsetshire on the summit of

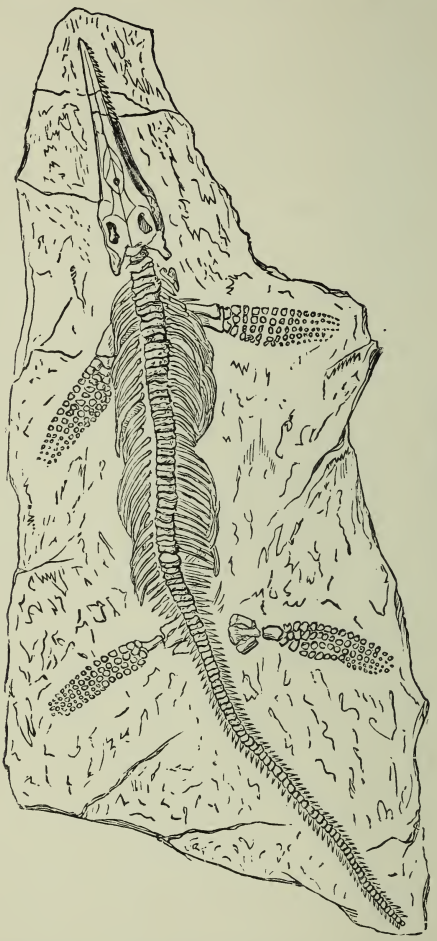

Fig. 16.—*Ichthyosaurus.*

Chideock Hill and near Sherborne and Yeovil station. At Midford in Somersetshire, Professor Phillips has found *Ammo-*

nites bifrons, *A. jurensis*, *A. striatulus*, *A. insignis*, and *A. opalinus*, with *Belemnites* such as *B. irregularis*, *B. breviformis*,

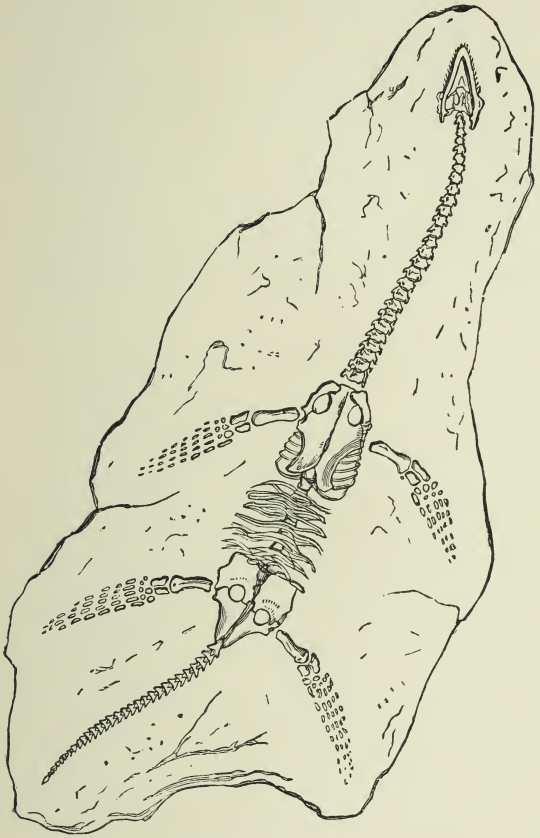

FIG. 17.—*Plesiosaurus.*

B. tripartitus, and *B. compressus;* and also a species of Nautilus, *N. inornatus.*

(5) The Zone of *Ammonites opalinus* is ill-defined. It can

be seen as a thin bed below the Inferior Oolite near Bridport in Dorsetshire.

The Lower or Bath Oolites rest conformably on the Upper Lias, and, as seen in the preceding table (p. 50) admit of subdivision into the Inferior Oolite, Fuller's Earth, and Great Oolite.

The *Inferior Oolite* attains its maximum thickness (264 feet) at Leckhampton Hill, near Cheltenham, where it is composed of chalky freestones and grits. Here a large number of fossils can be found, such as *Terebratula fimbria*, *T. globata*, *Lima cardiformis*, *Lucina lyrata*, *Mytilus pectinatus*, *Natica cincta*, *Gervillia tortussa*, *Gryphæa subloba*, *Rhynchonella spinosa*, *R. plicatella*, *Collyrites ringens*, *Clypeus sinuatus*, *Ammonites Martinsii* and *A. Parkinsoni*. The Inferior Oolite has been subdivided into the following four zones :—

(1) Zone of *Ammonites Parkinsoni*.
(2) ,, ,, ,, *Humphresianus*.
(3) ,, ,, ,, *Sowerbyi*.
(4) ,, ,, ,, *Murchisonæ*.

(1) The Zone of *Ammonites Parkinsoni* is to be found in the Inferior Oolite of Dorsetshire. The characteristic fossils are *Ammonites Parkinsoni*, *A. Truellii*, *A. garantianum*, and *A. polymorphum*, with the Lamp-shells *Rhynchonella spinosa*, *Terebratula Stephani*, *T. Phillipsi*, and *T. globata*.

(2) The Zone of *Ammonites Humphresianum* is found developed at Bridport, Sherborne, Lousehill, and Wyke in Dorsetshire, and at Dundry in Somersetshire. *Ammonites Edouardianum*, *A. cycloides*, *A. oolithicum*, *A. linguiforme*, *A. subfurcatum*, and *A. Wrightii* are well-known fossils of this zone, being confined to it.

(3) The Zone of *Ammonites Sowerbyi* contains *A. adricum*, *A. cornu*, *A. Levesquei*, *Lytoceras confusum*, with *Terebratula Eudesii*, *Astarte excavata*, and *A. elegans*. Favourite localities are in Wyke quarry and at Bradford Abbas.

(4) The Zone of *Ammonites Murchisonæ* is found at Dundry, near Cheltenham, and at Wyke and Bradford Abbas. Other than its characteristic fossil, *Terebratula perovalis*, *T. simplex*, *T. Etheridgii*, *Rhynchonella subangulata*, and *R. subtetraedra* are not uncommon.

Fuller's Earth is a clayey deposit well developed in the Cotteswold Hills, and near Bath and Stroud. An oyster (*Ostrea acuminata*) is very common; the other characteristic fossils are *Goniomya angulifera*, *G. literata*, *Pecten vagans*, *Rhynchonella concinna*, *R. varians*, *Terebratula ornithocephala*, *T. globata*, *Ceromya concentrica*, and *C. plicata*.

The Great or Bath Oolite Group is subdivided as seen in the table on p. 50. We shall then have to consider it as,—

(1) Great Oolite Proper.
(2) Bradford Clay and Forest Marble.
(3) Cornbrash.

The *Great Oolite* is quarried near Bath, at Minchinhampton near Stroud, Brimscombe, Burley, Box, Corsham, and on Combe Down and Farleigh Down; to any of which localities the student can go for his fossils. The "Stonefield Slates," composed of sandstones or flagstones, which are so hard as to split easily into fragments along the plane of bedding, are quarried on Sevenhampton Common, at Burford and Windrush, in the Evenlode valley at Woodstock and Saroden, and at Stonesfield in Oxfordshire. In the Stonesfield Slate perhaps the most interesting of all the fossils are the remains of insectivorous mammals which, probably, were pouched. One (*Phascolotherium*) is allied to the American opossums, another (*Amphitherium*) is related to the Australian banded ant-eater, and another (*Stereognathus*), which probably was herbivorous, Owen considers to belong to the hoofed group of mammals. It is also interesting that *Teleosauria*, *Ichthyosauria* and *Plesiosauria* are found associated with them. Flying lizards (*Pterosaurs*), *Deinosaurs*, and the carnivorous lizard *Megalosaurus*, are found in the Great Oolite, a noted locality being at Enslow Bridge, near Oxford.* The first butterfly, *Palæontina oolitica*, is found in the Stonesfield Slate. The fossils of the Great Oolite, other than those already mentioned, are represented by Lamp-shells belonging to the genera *Rhynchonella*, *Waldpora*, and *Terebratula*, by Lamellibranchs of the genera *Lima*, *Ostrea*, *Pecten*, *Astarte*, *Pholadomya*, *Cardium*, *Avicula*, and *Modiola*, and by Gastropods of the genera *Patella*, *Murex*, *Nerita*, *Buccinum*,

* From this locality a magnificent Deinosaur (*Cetiosaurus oxoniensis*) has been unearthed, probably measuring in length fifty feet or more.

Actæonina, *Nerinæa*, and *Fusus*. The Belemnites *B. bessinus* and *B. aripistellium*, and the Ammonites *A. gracilis*, *A. micromphalus*, *A. arbustigerus*, and *A. discus* occur. Corals are especially abundant; and so are fish belonging to the genera *Ganodus*, *Hydobus*, *Lepidotus*, *Pycnodus*, and *Strephodus*.

The *Bradford Clay* and *Forest Marble*. The Bradford Clay is well developed at Bradford in Wiltshire, where a pear-shaped stone-lily (*Apiocrinus rotundus*) occurs with its base resting on the Great Oolite limestone; other fossils are *Terebratula digona*, and *Avicula costata*. The Forest Marble is well developed in Dorsetshire, where it is 450 feet thick. The fossils are few. Echinoderms are the most characteristic fossils; these are *Apiocrinus elegans*, *Astropecten Huxleyi*, *A. Phillipsii*, and *Hemicidaris alpina*. Gastropods are also common.

The *Cornbrash*, a coarse ferruginous limestone, bluish-grey in colour, is found in Oxfordshire, Yorkshire, Lincolnshire, Northamptonshire, and Huntingdonshire. Fossils of Echinoderms, Lamellibranchs, and Gastropods are the most common. Of Echinoderms, *Echinobrissus clunicularis* and *Holectypus depressus;* of Lamellibranchs, *Avicula echinata*, *Hinnites gradus*, *Lima duplicata*, *L. pectiniformis*, *Ostrea flabelloides*, *Cardium latum*, *Leda variabilis*, and *L. rostralis;* of Gastropods, *Actæonina marginata*, *A. scarburgensis*, *Ceritella costata*, *Dentalium entaloideum*, *Natica punctata*, and *Pleurotomaria granulata*.

The Middle or Oxford Oolites are divided into (1) Oxfordian and (2) Corallian.

The Oxfordian is divided into two sections: (*a*) Kellaways Rock, and (*b*) Oxford Clay.

The *Kellaways Rock*, composed of calcareous sandstone, will be well seen near Kellaways Bridge in Wiltshire, at North Cliff, Scarborough; under High Red Cliff, south-east of Wheatcroft, and along the Gristhorpe Cliff to Newbiggin. Ammonites and Belemnites are common. The common Ammonites are *A. Kœnigi*, *A. macrocephalus*, *A. Gowerianus*, *A. modiolaris*, and *A. calloviensis;* the common Belemnites are *B. Owenii* and *B. hastatus*. *Lima notata*, *Gryphæa bilobata*, and *Astropecten arenicolus* are common fossils.

The *Oxford Clay* is to be found from the Dorsetshire coast northwards to Scarborough as a deposit of stiff blue and brown clay. The characteristic fossils are *Ammonites cordatus*, *A. Lamberti*, *A. vertebralis*, *A. crenatus*, *Pecten vagans*, *Modiola bipartita*, *Astarte carinata*, *Rhynchonella socialis*, and the

Belemnites *B. Owenii* and *B. hastatus*. Numerous reptiles have also been found.

The *Corallian*, composed of the Coral Rag and Calcareous Grit, is a well-known Oolite Series. Good localities to collect are on the south side of the Great Vale at Oswaldkirk and Hovingham to Malton, on the northern side of the Vale of Pickering, near Weymouth, Abbotsbury, Westbury, Highworth, South Quarry, Faringdon (near the Lamb Inn, six miles distant), the Castle Howard Park Quarry, and at Nunnington in Yorkshire. Large branching corals belonging to the species *Thamnastræa arachnides*, *T. rotata*, *Isastræa explanata*, *I. Greenoughii*, *Thecosmilia annularis*, *Rhabdophyllia Phillipsii*, *R. Edwardsii*, *Comoseris irradians*, and *Gonicera socialis* are frequent; also sea-urchins, especially *Cidaris florigemma*. Lamp-shells are somewhat rare; they are represented by the genera *Terebratula*, *Rhynchonella*, *Lingula*, *Discina*, *Waldheimia*, *Zelania*, and *Thecidium*. Lamellibranchs belonging to the genera *Avicula*, *Lima*, *Pecten*, *Gryphæa*, and *Ostrea*, occur in plenty; the most common species are *Gryphæa dilatata* and *Ostrea gregarea*. Sixty species of Gastropods are peculiar to the Corallian; some of the commoner forms are *Littorina muricata*, *Actæon retusus*, *Dentalium annulatum*, *Pleurotomaria granulata*, and *Alaria bispinosa*. One Nautilus, *N. hexagonus*, is known; the distinctive Ammonites are *A. Williamsoni*, *A. pseudo-cordatus*, *A. plicatilis*, *A. anceps-albus*, *A. Babeanus*, *A. retroflexus*, *A. Sutherlandiæ*, *A. rupellensis*, and *A. cadonensis*. Belemnites are poorly represented by three species, *B. abbreviatus*, *B. hastatus* and *B. excentricus;* and three reptiles only have been found, viz., *Chelys Blakii*, *Megalosaurus Bucklandii*, and a species of *Pliosaurus*.

The *Upper* or *Portland Oolites* are divisible into three groups—the Kimeridgian, Portlandian, and Purbeckian. The Kimeridgian (or as it is generally wrongly given, Kimmeridgian) consists of shales, clays, and cement stone. It is seen well exposed at Gad Cliff and St. Alban's Head in the Isle of Purbeck, at Market Rasen, near Swindon in Wiltshire, and near Oxford. The interest of this group lies in the fact that "it has supplied the largest number (forty-five species) of the Mesozoic genera and species of reptiles yet found in Britain," and these represent six orders, viz., the Chelonia, Crocodilia, Ichthyopterygia, Sauropterygia, Pterosauria and Deinosauria. Prof. Etheridge thus tabulates the genera,—

		Species.
Crocodilia.	Bothriospondylus	1
	Dakosaurus	3
	Steneosaurus	5
	Teleosaurus	2
Chelonia.	Enaliochelys	1
	Pelobatochelys	1
Ichthyopterygia.	Ichthyosaurus	6
	Ophthalmosaurus	1
Sauropterygia.	Plesiosaurus	12
	Pliosaurus	5
Pterosauria (Ornithosauria *Seeley*).	Pterodactylus	2
Deinosauria.	Cetiosaurus	1
	Cryptosaurus	1
	Gigantosaurus	1
	Iguanodon	1
	Megalosaurus	1
	Omosaurus	1
		45

Foraminifera are numerous, especially *Pulvulina pulchella* and *Robulina Münsteri;* Echinoderms, as *Cidaris spinosus*, *C. baculifera*, *C. boloniensis*, *Pentacrinus sigmaringensis*, and *Hemipedina Cunningtoni* are found. The Lamellibranchs are chiefly *Ostrea expansa*, *Exogyra nana*, *E. spiralis*, *Perna mytiloides*, *Cardium striatulum*, *Honomya gracilis*, *Goniomya minuta*, *Thracia depressa*, *Trigonia incurva*, and *Modiola bipartita;* the commoner Ammonites are *A. decipiens*, *A. Kapfii*, *A. mutabilis*, *A. accipitris*, *A. Benyeri*, *A. Beaugrandi*, *A. flexuosus*, and *A. lallerianus.*

The *Portlandian* will be found exposed in the Vale of Wardour, at St. Alban's Head, in the island of Portland, at Brill and Crendon in Buckinghamshire, in the Swindon quarries, and at Hazely, Shotover, Great Milton, Coddesdon, and Garsington in Oxfordshire. They consist of limestone and calcareous freestone, with sands (Portland Sand). Common fossils at Portland are *Cerithium Portlandicum*, *Ostrea multiformis*, *Natica elegans*, *Trigonia gibbosa*, *Serpula gordialis*, *Cardium dissimile*, *Cyprina elongata*, *Ammonites pseudogigas*, *A. triplex*, *Pleurotomaria rugata*, *Pecten lamellosus*, and *Lima rustica.*

Many of these fossils are found in the Vale of Wardour; *Trigonia Pellati*, *T. variegata*, *T. concentrica*, *Mytilus jurensis*, *Pecten concentricus*, *Astarte supra-corallina*, *Nerita transversa*, *Cerithium concavum*, *Lucina Portlandica*, *Pleuromya tellina*, and *Neritoma sinuosa* are common. The Swindon quarries are especially good collecting grounds.

The *Purbeckian*, so called from the occurrence of these strata in the Isle of Purbeck in Dorsetshire, is generally classified as the highest zone of the English Jurassic Series. There is a physical break, however, between this group and the Portlandian. Divided into three sub-groups, the lowest consists of limestones and clays of fresh-water origin, the middle of marine limestone, and the upper of fresh-water beds. The student who has studied the author's "Land and Fresh-water Shells" in this series will meet here with shells belonging to genera well-known to him, such as *Paludina*, *Limnæa*, *Hydrobia*, *Physa*, *Planorbis*, *Valvata*, *Unio*, and *Sphærium*. Fish scales, teeth, spines, and palates are frequent of the placoid and ganoid type; the chief species are *Lepidotus minor*, *Microdon radiatus*, *Histionotus angularis*, *Oxygonius tenuis*, and *Leptolepis Brodiei*. *Ostrea distorta* and species of *Avicula*, *Thracia*, *Modiola*, and *Pecten* are characteristic of the marine strata. The Crocodiles are represented by the genera *Theriosuchus*, *Pterosuchus*, *Nannosuchus*, *Macrorhynchus* and *Goniopholis;* the Lizards by *Nuthetes*, *Saurillus*, *Macellodon* and *Echinodon;* the Chelonia by *Pleurosternon*, *Tretosternon* and *Chelone;* and the Pterosaurs by *Doratorhynchus*. Working places are near Battle in Sussex, at Lulworth, and in the Isle of Purbeck. In what is called the "dirt-bed" at Lulworth, stumps of a Cycad (*Mantellia nidiformis*) are frequent. Beetles, locusts, bugs, dragon-flies, and flies were common during the formation of this group; no less than ninety-five species have been described. The crocodile, *Theriosuchus*, was only eighteen inches long. Mammals roamed the woods and pastures, and these were all marsupials, like the present kangaroo of Australia. They are *Peramus tenuirostris*, *Perlastes longirostris*, *Perlastes species*, *Achyrodon nanus Amblotherium soricinum*, *A. mustelula*, *Peraspalax talpoides*, *Plagiaulax minor*, *P. medius*, *P. Falconeri*, *P. Becklesii*, *Stylodon robustus*, *S. pusillus*, *Triconodon ferox*, *T. mordax*, *T. major*, *T. occisor*, *Belodon crassidens*, *Spalacotherium minus* and *S. tricuspidens*. Our knowledge of these pouch-bearing mammals, which lived at the time of the deposition of these beds, is

gained chiefly from lower jaws, which have been found in a thin stratum near the base of the Middle Purbeckian.

The Cretaceous Period is separated from the Jurassic by a well-marked unconformability in the rocks, and by a break in the palæontological character of the life of the two periods. In England the strata belonging to this period attain a maximum thickness of about 4,100 feet, a figure which does not approach the thickness of 13,000 feet, found as the thickness of an unbroken series in the Territories of Utah and Wyoming in the United States. Their lithological character varies from soft clays, sands, and glauconitic sandstones to chalk (Latin, *creta*, hence the name). During this period the Atlantic Ocean covered the south of Europe, the northern part of Africa, and a large portion of Asia, and probably, as is pointed out by Geikie, was connected with the Indian Ocean. We shall best consider the rocks of the period under the following sub-divisions :—

Lower Cretaceous	1. Wealden.
	2. Lower Greensand, or Upper Neocomian.
Upper Cretaceous	3. Gault.
	4. Upper Greensand.
	5. Chloritic Marl.
	6. Chalk Marl.
	7. Grey Chalk.
	8. Lower Chalk.
	9. Upper Chalk.

The *Wealden* consists of a series of fresh-water and estuarine strata found in those parts of Kent, Surrey, and Sussex called the Weald.* The strata are chiefly composed of sands, sandstones, clays, and limestones. They are, however, not confined to the Weald, but are also found in Dorsetshire and the Isle of Wight. The strata, in fact, represent the delta of a large river which probably drained a continent which might have been as large, or even larger, than Asia. "If it be asked," says Sir Charles Lyell, "where the continent was placed from the ruins of which the Wealden strata were derived, and by the drainage of which a great river was fed, we are half tempted to speculate on the former existence of the Atlantis of Plato. The story of the submergence of an ancient continent, however fabulous in history, must have been

* "Weald" or "wold" is an old English word for "woodland."

true and true again as a geological event." Various shells, belonging to the genera *Unio*, *Sphærium*, *Cyrena*, *Paludina*, and *Melania* are found, with now and then a specimen of a

FIG. 18.—Fossils of the Cretaceous System.

Lower Cretaceous: 1, *Spatangus* (*Toxaster complanatus*); 2, *Rhynchonella depressa*; 3, *Caprotina ammonia*; 4, *Aptychus didayi*. Gault (Middle Cretaceous of Germany); 5, *Hamites attenuatus*; 6, *Scaphites Yvanzi*; 7, *Ancyloceras Matheronianus*; 8, *Turrilites bergeri*. Upper Cretaceous: 9, *Baculites anceps*; 10, *Ammonites rothomagensis*; 11, *Inoceramus concentricus*; 12, *Exogyra columba*; 13, *Spondylus spinosa*; 14, *Hippurites cornu-vaccinum*; 15, *Caprina aguilloni*; 16, *Terebratula carnea*; 17, *Actæonella gigantea*; 18, *Nerinæa flexuosa*; 19, *Belemnitella mucronata*; 20, *Cyclolites elliptica*; 21, *Ananchytes ovatus* (side view); 22, *Ananchytes ovatus* (from below); 23, *Otodus appendiculatus*; 24, *Oxyrhina Mantelli*.

marine genus, as *Ostrea* and *Mytilus*. *Paludina fluviorum* and *P. Sussexensis* are common shells. Ostracods, as *Cypris Va'densis*, *C. spinigera*, and *C. tuberculata* are characteristic of the

clay and other beds. The clay of this formation is so tenacious that William Cobbett, in the days of very bad roads (happily now, in the majority of cases, a thing of the past), wrote in his "Rural Rides": "From Ewhurst the first three miles was of the deepest clay that I ever saw to the best of my recollection. I was warned of the difficulty of getting along; but I was not to be frightened at the sound of clay. It took me a good hour and a half to get along these three miles. Now mind, this is the real Weald, where the clay is bottomless." A fresh-water fish (*Lepidotus*), allied to the American gar swam in the waters of the Wealden rivers. Huge reptiles tramped the swamps, and devoured the leaves of the Cycads and ferns. Their remains have been unearthed from the Black Horse Quarry on Tetham Hill near Hastings, and include species of *Iguanodon*, *Megalosaurus*, *Teleosaurus*, and *Plesiosaurus*, with flying reptiles (*Pterodactylus*). One of them (*Iguanodon Mantellii*) was 35 feet long and 20 feet in girth. A foreign species (*Iguanodon bernissartensis*), found near Bernissart, is now in the Brussels Museum, whose thighs probably had a girth of six or seven feet!

The *Lower Greensand*, unlike the Wealden, is composed of marine strata. The name of Greensand has been given to it, because the strata contains grains of a greenish-coloured mineral termed glauconite (see Glossary); but as these grains occur sparingly, and the general colour of the strata is not green, but brownish-red, the name is not appropriate; a better name would be Vectian, as suggested by Mr. Jukes-Browne, from the word Vectis or Vecta, the Latin name for the Isle of Wight, where these strata are well shown. The Atherfield Clay, exposed in cliffs on the south of the Isle of Wight, is a good locality for collecting specimens. *Toxaster complanatus*, *Ostrea Couloni*, *O. Leymeriei*, *Arca Raulini*, *Perna Mulleti* and *Terebratula sella* are common. On breaking the nodules, large specimens of *Ammonites Deshayesii* may be obtained. The same kind of bed is exposed at low tide opposite Shorncliffe Battery in Kent, and it is also seen in the railway cutting at Red Hill. At this last locality *Pecten obliquus*, *Pinna sulcifera*, *Gryphæa sinuata*, *Perna Mulleti*, *P. alæformis*, *Panopæa depressa*, *Arca Raulini*, *Trigonia dædalea*, and *Nautilus radiatus* may be obtained. The Hythe beds, shown at Hythe, Lympne, Sevenoaks, and Maidstone, yield a large number of fossils, as *Ammonites Deshayesii*, *A. cornuelianus*, *Plicatula*

placunea, *Crioceras Bowerbankii*, and *Belemnites semicanaliculatus*. The cliffs near Folkestone give twenty-four species, but they are, for the most part, in a broken condition. Near Pulborough and at Codmoor Hills, in what are called the "Sandgate Beds," specimens of *Thetis Sowerbyi*, *Trigonia alæformis*, *Cyprina angulata*, and *Rhynchonella Gibbsiana* may be found in the nodules.

The *Gault*, a stiff-blue clay, speckled with mica flakes, and containing calcareous nodules, is found well developed in East-Wear Bay near Folkestone; near Eastbourne; at Black-Gang, Wroxhall, Ventnor, and Bonchurch in the Isle of Wight; at Pinhay Cliff near Lyme Regis, Stonebarrow, Black Ven, and Golden Cap in Dorsetshire; at Barton, and Arlesey in Bedfordshire, and at Bassingbourne, and Guilden Morden in Cambridgeshire. De Rance and Price,* classify the Gault at Cope Point near Folkestone, as follows :—

Upper Greensand.

Upper Gault.

11. Pale grey marly clay (56 ft. 3 in.) characterized by *Ammonites rostratus* (*inflatus*), *A. Goodhalli*, *Ostrea frons*, *Inoceramus Crispii*.
10. Hard pale marly clay (5 ft. 1 in.) with *Kingena lima*, *Rostellaria maxima*, *Plicatula pectinoides*, *Pecten raulinianus*, *Pentacrinus Fittoni*, *Cidaris gualtina*.
9. Pale grey marly clay (9 ft. 4½ in.) with *Inoceramus sulcatus*, *Ammonites varicosus*, *Pholadomya fabrina*, *Pleurotomaria Gibbsii*, *Scaphites æqualis*.
8. Darker clay, with two lines of nodules and rolled fossils (9½ in.) with *Ammonites cristatus*, *A. Beudanti*, *Pholas sanctæ-crucis*, *Mytilus Galliennei*, *Cuccullæa glabra*, *Cyprina quadrata*.

Lower Gault.

7. Dark clay (6 ft. 2 in.) highly fossiliferous, with *Ammonites auritus*, *Nucula bivirgata*, *N. ornatissima*, *Aporrhais Parkinsoni*, *Fusus indecisus*, *Pteroceras bicarinatum*.
6. Dark mottled clay (1 ft.), *Ammonites denarius*, *A. cornutus*, *Turrilites hugardianus*, *Necrocarcinus Bechei*.
5. Dark spotted clay (1 ft. 6 in.), *Ammonites lautus*, *Astarte dupiniana*, *Solarium moniliferum*, *Phasianella ervyana*, numerous corals.
4. Paler clay (4 in.), *Ammonites Delaruei*, *Natica obliqua*, *Dentalium decussatum*, *Fusus gaultinus*.

* Geikie, "Text-Book of Geology," p. 825.

Lower Gault.

3. Light fawn-coloured clay, "crab-bed" (4 ft. 6 in.) with numerous carapaces of crustaceans (*Palæocorystes Stokesii*, *P. Broderipii*), *Pinna tetragona*, *Hamites attenuatus*.
2. Dark clay marked by the rich colour of its fossils (4 ft. 3 in.), *Ammonites auritus*, *Turrilites elegans*, *Ancyloceras spinigerum*, *Aporrhais calcarata*, *Fusus itierianus*, *Cerithium trimonile*, *Corbula gualtina*, *Pollicipes rigidus*.
1. Dark clay, dark greensand, and pyritous nodules (10 ft. 1 in.), *Ammonites interruptus*, *Crioceras astierianum*, *Hamites rotundus*.

Lower Greensand.

At Black Ven in Dorsetshire, *Trigonia alæformis*, *T. scabra*, *Cardium gentianum*, *Turritella granulata*, *Pleurotomaria Rhodani*, *Thetis Sowerbyi*, *Cytherea plana*, *Hoploparia longimana* and *Necrocarcinus Bechei* may be obtained; at Eastbourne, *Hamites armatus*, *Pecten orbicularis*, *Dentalium decussatum*, *Terebratula biplicata*, *Ammonites rostratus*, *Belemnites attenuatus*, *B. minimus*, and *Exogyra conica* are the principal fossils.

The *Upper Greensand* is composed of greenish sand and sandstones, the green colour being due to grains of glauconite. It forms the base of the chalk from Lynn in Norfolk to Dorsetshire, and attains a maximum thickness of about 100 feet. At Petersfield it is 80 feet thick, in the Wealden area about 60 feet, at Godalming 50 feet, and at Eastbourne and Nutfield 40 feet. Blackdown and Warminster are good collecting places. The commoner fossils of the "Warminster beds" are *Ammonites varians*, *A. Mantelli*, *A. Coupei*, *Belemnites ultimus*, *Ostrea frons*, *Terebratula squamosa*, *T. biplicata*, *Terebratella pectita*, *Rhynchonella compressa*, *R. latissima*, *Pecten asper*, *Peltastes clathratus*, *Discoidea subucula*, and *Pseudodiadema Michelini*. The "Blackdown beds" contain *Ammonites Goodhalli*, *A. varicosus*, *Cyprina angulata*, *Cytherea plana*, *Trigonia alæformis*, *T. scabricola*, *Exogyra conica*, *Lima sulcata*, *Thetis gigantea*, *Pecten quadricostatus*, *Inoceramus concentricus*, *Gervillia anceps*, *Pectunculus umbonatus*, *Cucullæa carinata*, and the following Gastropods—*Aporrhais Parkinsoni*, *Dimorphosoma calcarata*, *Natica gualtina*, *Actæon affinis*, and *Turritella granulata*. Godwin-Austen considered the "Blackdown beds" as a sandy shore representative of the Gault.

The *Chloritic* or *Glauconitic Marl* is a name applied to a white marl found below the true chalk, containing phosphatic nodules, and grains of glauconite. *Terebratula biplicata*, *Tur-*

rilites tuberculatus, *Solarium ornatum*, *Plicatula inflata*, *Nautilus lævigatus*, *Ammonites Mantelli*, *A. Coupei*, *A. laticlavius*, and *A. varians* are among its fossils.

The *Chalk Marl*, a clayey chalk, also forming the base of the true chalk, will be found well exposed at East-Wear Bay near Folkestone, and in the Isle of Wight. The principal fossils are *Inoceramus striatus*, *Lima globosa*, *Holaster lævis* (var. *nodulosus*), *Plocoscyphia meandrina*, *Rhynchonella Martini*, *Plicatula inflata*, *Scaphites æqualis*, *Turrilites costatus*, and *Ammonites Mantelli*, *A. varians*, *A. falcatus*, *A. cenonnanensis*, and *A. navicularis*.

The *Grey Chalk* forms the lower part of the chalk proper, and can be seen well developed along the shore-cliffs of Kent. Here, according to Mr. Price, it is divisible into five beds,—

1. Containing *Ammonites varians*, *Pecten Beaveri*, *Discoidea subucula* (8 feet thick).

2. Containing *Ammonites Lewesiensis*, *A. rothomagensis* and *A. Mantelli* (11 feet thick).

3. Containing *Hemiaster Morrisii*, *Terebratula rigida*, *Peltastes clathratus*, *Rhynchonella mantelliana*, *Ammonites varians* and *A. rothomagensis* (2 feet 9 inches thick).

4. Containing *Holaster subglobosus*, *Goniaster mosaicus*, *Belemnitella plena*, *Discoidea cylindrica* (148 feet thick).

5. Containing *Ptychodus*, *Hippurites Mortoni* and *Belemnitella plena* (4 feet thick).

At Burwell, in Cambridgeshire, what is known as the "Totternhoe Stone" occurs as a hard, grey, sandy limestone. The majority of the fossils of this "Stone" are in the Woodwardian Museum. The principal are *Scalaria fasciata*, *Lima echinata*, *Pecten fissicosta*, *P. opercularis*, *Pinna tegulata*, *Ammonites cenomanensis*, and *A. varians*.

The *Lower Chalk* (*without flints*), can be traced from Flamborough Head in Yorkshire into Dorsetshire; it can be well seen in the Kent cliffs. Composed of the shells of foraminifera, urchins, molluscs, etc., it suggests some resemblance to the globigerina-ooze now forming on the bed of the Atlantic Ocean. However, there is no evidence that the chalk was deposited in such abysmal depths. The chief fossils found in the Kent cliffs are *Inoceramus labiatus*, *I. Cuvieri*, *Terebratula semiglobosa*, *Terebratulina gracilis*, *Rhynchonella Cuvieri*, *Echinoconus subrotundus*, *Holaster planus*, and *Cardiaster pygmæus*.

The *Upper Chalk* (*with flints*) does not differ in general appearance from the Lower Chalk (without flints), except that the lines of stratification are marked by layers of flint nodules, and, now and then, by sheets of flinty material. The Upper Chalk can be divided into three divisions :—1, The Broadstairs and St. Margaret's Chalk ; 2, the Margate Chalk ; and, 3, the Norwich Chalk.

The Broadstairs and St. Margaret's Chalk, known also as the Micraster division, contains few fossils, but the chief of these are *Micraster cor-testudinarium*, *M. cor-anguinum*, *Echinocorys gibbus*, *Echinoconus conicus*, *Cidaris clavigera*, *Epiaster gibbus*, *Terebratulina gracilis*, *Terebratula semiglobosa*, *Inoceramus involutus*, and *Ostrea vesicularis*. The student working at this division, should consult Mr. Whitaker's paper in the fourth volume of the "Memoirs of the Geological Survey."

The Margate Chalk, called by Dr. Barrow the Marsupite Zone, contains a large number of Crinoids. *Cidaris clavigera*, *C. sceptrifera*, *Amorphospongia globosa*, *Marsupites ornatus*, *M. Milleri*, *Micraster cor-anguinum*, *Bourgueticrinus ellipticus*, *Echinoconus conicus*, *Echinocorys gibbus*, *Terebratula semiglobosa*, *Rhynchonella plicatilis*, *Spondylus* (*Lima*) *spinosus*, *Terebratulina striata*, *Inoceramus lingua*, *Pecten cretosus*, *Ostrea hippopodium*, *O. vesicularis*, *Belemnites versus*, and *Ammonites leptophyllus* are among its fossils. In the Isle of Thanet this division attains a thickness of about 80 feet.

The Norfolk Chalk, seen at Norwich as a white, crumbling chalk containing black flints, possesses among others the following fossils : *Trochosmilia laxa*, *Salenia geometrica*, *Cyphosoma magnificum*, *Parasmilia centralis*, *Echinocorys ovatus*, *Rhynchonella otoplicata*, *R. limbata*, *Terebratula carnea*, *T. obesa*, *Ostrea lunata*, *Belemnitella quadrata*, and *B. mucronata*.

In Yorkshire, the chalky downs called the "Wolds" may be worked with advantage. The *Placoidei* (carnivorous fish), found in the Kent Chalk, however, do not occur in the Yorkshire Chalk.

CHAPTER IV.

THE LIFE OF THE TERTIARY OR CAINOZOIC EPOCH.

We shall consider this epoch of "recent life" under its four periods:—(1) Eocene, (2) Oligocene, (3) Miocene, and (4) Pliocene.

The Eocene Period, so called from two Greek words, meaning dawn (*eos*), and recent (*kainos*), will be considered as to its "life," under the headings of, (*a*) the Thanet Sands, (*b*) the Woolwich and Reading Series, (*c*) the Oldhaven beds, (*d*) the London Clay, and (*e*) the Bagshot Sands.

The *Thanet Sands* are marine sands, yellowish or greenish in colour, found in the London area; they are well exposed at Crayford, Chislehurst, Charlton pits, Sittingbourne, St. Mary Cray, Epsom, and in an outlier at Well Hill. The commoner shells are *Pecten Prestwichii*, *Ostrea bellovacina*, *O. cymbuloides*, *Cardium Laytoni*, *Cucullæa decussata*, *Glycimeris rutupiensis*, *Nucula margaritacea*, *N. Thanetiana*, *Pholadomya cuneata*, *Panopæa granulata*, *Sanguinolaria Edwardsii*, *Fusus tuberosus*, *Ringinella turgida*, *Scalaria Bowerbankii*, and *Aporrhais Sowerbyi*.

The *Woolwich and Reading Series* consists of mottled clays, gravels, and sands of marine and estuarine origin. They are well seen at St. Mary Cray, Bushey, Hatfield Park, Watford, and near Hertford. In the Isle of Wight, at Whitecliff Bay, fine sections are shown. The marine shells are *Arca Dulwichensis*, *Cardium Laytoni*, *Corbula regulbiensis*, *Cyprina Morrisii*, *Glycimeris rutupiensis*, *Modiola elegans*, *Pectunculus terebratularis*, *Ostrea bellovacina*, *Cytherea orbicularis*, *Cerithium funatum*, *C. gracile*, *Calyptræa trochiformis*, *Melanopsis buccinoides*, *M. ancillaroides*, *Natica subdepressa*, and *Modiola elegans*; the estuarine are *Paludina aspera*, *Hydrobia Parkinsoni*, *Cyrena cordata*, *C. cuneiformis*, and *Melania inquinata*; the fresh-water, *Dreissina serrata*, *Planorbis homistoma*, and

Unio Solandri. Bones of turtles, mammals (*Coryphodon*), and sharks (*Lamna*), with one or two terrestrial plants, as *Ficus Forbesii*, *Laurus Hookeri*, and *Grevillea Heeri*, have also been found.

The *Oldhaven beds* overlie the Woolwich beds in Surrey. At Reculvers, *Cyprina Morrisii* and *Cardium Laytoni* may be found. They consist of pebble beds and pebbly sands.

FIG. 19.—Eocene Fossils.

1, *Nummulites* (transverse and vertical sections); 2, *Nautilus* (*Aturia*) *lingulatus*; 3, *Carcharodon heterodon* (a shark's tooth); 4, Pseudo-fucoids (doubtful seaweeds); *Chrondrites intricatus*; and 5, *Chrondites targionii*, from the "Flysch" Formation, now considered—like *C. bollensis* of the Lias, and *C. ehingensis* of the White Jura—to be worm tracks.

The *London Clay* is a deposit of dark brown or greyish clay, with septarian nodules of clayey limestone. It is best shown in the Isle of Sheppey, from whence the majority of fossils have been taken. Underlying it is a bed consisting of green and yellow pebbly sands, to which Professor Prestwich has given the name of the "Basement-Bed." In it the chief fossils are *Cardium Laytoni*, *Panopæa intermedia*, *Pectunculus Plumsteadiensis*, *P. brevirostris*, *Natica labellata*, *Calyptræa trochifor-*

mis, *Cytherea obliqua*, *C. orbicularis*, *Cassidaria striata*, and *Aporrhais Sowerbyi*.

Classifying the characteristic fossils of the London Clay, we have :—

Plants.—Belonging to the genera *Callitrites*, *Pinus*, *Musa*, *Magnolia*, *Juglans*, *Cupanoides*, *Faboidea*, *Hightea*, *Leguminosites*, *Nipadites*, *Quercus*, *Eucalyptus*, *Amygdalus*, etc.

Foraminifera.—Belonging to the genera *Nodosaria*, *Miliola*, *Planorbulina*, *Dentalina*, *Textularia*, *Nodosarina*, etc.

Actinozoa, as *Mopsea costata*, *Paracyathus brevis*, *P. caryophyllus*, *Oculina Wetherellii*, *Leptocyathus elegans*, *Dasmia Sowerbyi*, etc.

Echinodermata.—Belonging to genera *Goniaster*, *Pentacrinus*, *Astropecten*, *Cainocrinus*, *Echinus*, *Cælopleurus*, *Schizaster*, *Hemiaster*, and *Bourgueticrinus*.

Fig. 20.—*Aturia zic-zac*.

Crustacea.—Represented by the genera *Xanthopsis*, *Scyllarida*, *Mithracia*, *Rachiostoma*, *Ædisoma*, etc.

Brachiopoda.—Two species only, *Lingula tenuis* and *Terebratulina striatula*.

Lamellibranchiata.—As *Anomia scabrosa*, *Ostrea cariosa*, *O. pulchra*, *Pecten duplicatus*, *P. corneus*, *Pinna affinis*, *Avicula arcuata*, *Corbula pisum*, *Leda minima*, *Cardita Davidsoni*, *Modiola hastata*, *Nucula similis*, etc.

Gastropoda.—As *Pleurotoma symmetrica*, *Cypræa oviformis*, *Fucus Pyrus*, *Murex minax*, *Voluta denudata*, *Solarium canaliculatum*, *Natica labellata*, etc.

Cephalopoda.—Represented by the genera *Nautilus*, *Aturia*, *Beloptera*, *Belemnosis*, and *Belosepia*.

Pisces.—Belonging to the genera *Otodus*, *Pycnodus*, *Phyllo-*

dus, *Myliobatis*, *Lamna*, *Periodus*, *Elasmodus*, *Ætobatis*, *Cœlorhynchus*, and *Carcharadon*.

Reptilia.—The Cheloniæ are represented by the genera *Chelonia*, *Emys*, *Trionyx*, and *Platemys*; the snakes by *Palæophis longus*, and *P. toliapicus*; the crocodiles by *Crocodilus champsoïdes*, and *C. toliapicus*.

Aves.—Represented by *Halcyomis toliapicus*, *Dasornis Londinensis*, *Odontopteryx toliapicus* (a web-footed bird with bony teeth), *Lithornis vulturinus*, and *Argillornis longipennis*.

Mammals.—Represented by an opossum (*Didelphys*), tapirs (*Coryphodon*), a hog (*Hyracotherium*), and a bat.

The *Bagshot Sands* are a series of sands of a yellow colour with irregular clayey beds. They, for the most part, are unfossiliferous. In what are known as the Bracklesham beds (found at Bracklesham on the Sussex coast) numerous fossils, however, are found; such as *Cyprœa inflata*, *C. tuberculosa*, *Voluta crenulata*, *V. spinosa*, *Mitra labratula*, *Conus Lamarckii*, *Murex asper*, *Lima expansa*, *Nucula minor*, *Avicula media*, *Cardita elegans*, *Fusus longævus*, etc. In the cliffs of Barton and Hordwell in Hampshire greyish and brownish clays with bands of sand occur, known as the "Barton Clay." Here may be found *Voluta luctatrix*, *V. athleta*, *Conus dormitor*, *C. scabriculus*, *Pleurotoma rostrata*, *Pecten reconditus*, *Lima compta*, *Modiola seminula*, *Ostrea gigantea*, *Pectunculus deletus*, and *Arca appendiculata*.

The Oligocene Period.—The strata belonging to this period consist of clays, marls, sands, and limestones, alternating in beds with one another; they are sparingly developed in Britain. Sections may be seen at Headon Hill, Brockenhurst, Colwell Bay, and Whitcliff Bay in the Isle of Wight. The commoner fossils are *Limnæa longiscata*, *L. caudata*, *Planorbis euomphalus*, *P. lens*, *Paludina lenta*, *Cyrena cycladiformis*, *Unio Solandri*, *Cerithium concavum*. *C. lepidum*, *C. pseudocinctum*, *Cytherea incrassata*, *Ostrea flabellula*, *Nucula similis*, *Conus dormitor*, *Cardita deltoidea*, *Voluta spinosa*, and *Pleurotoma transversaria*. From Bovey-Tracey, in Devonshire, numerous plants have been taken which are indicative of a sub-tropical climate.

The Miocene Period is not represented in our rocks. Britain was a land-surface at the time.

The Pliocene Period.—The rocks belonging to this period are locally known as "crags." We have—

(1) The Coralline, or White, Crag.
(2) The Red Crag.
(3) The Norwich, or Mammaliferous, Crag.
(4) The Chillesford Beds, and
(5) The Forest Bed Group.

The *Coralline*, or *White, Crag* is a local Suffolk formation, found around Orford, Woodbridge, Aldborough, Gedgrave, Sutton, Sudborne, and Ramsholt. It consists of soft sands and flaggy limestone, and in some places is composed almost entirely of the remains of polyzoa.* Eighty-four per cent. of the shells it contains are still living. The principal are *Terebratula grandis*, *Terebratula caput-serpentis* (these are Brachiopods), *Lingula Dumortieri*, *Pecten opercularis*, *Pholadomya histerna*, *Pyrula reticulata*, *Fascicularia aurantium*, *Buccinum undatum*, *Nassa incrassata*, *Cyprœa Europœa*, *Trochus Zizyphinus*, *Fusus antiquus*, *Saxicava rugosa*, *Solen ensis*, *Tellina crassa*, *Cardium nodosum*, *Turritella incrassata*, *Natica multipunctata*, and *Scalaria cancellata*.† The characteristic polyzoa belong to the genera *Membranipora*, *Tubulipora*, *Hornera*, *Idmonea*, *Cellepora*, and *Eschara*. *Mastodon arvernensis*, *Rhinoceros Schleiermacheri*, *Cervus dicranoceros*, *Balœna mysticetus*, and *Balœnodon physaloides* are among the mammals. Notice in the Mollusca, the almost total absence of genera belonging to a hot climate.

The *Red Crag* consists of red and brown ferruginous sands. Ninety-two per cent. of the shells belong to still living species. *Cardium echinatum*, *C. interruptum*, *Mya arenaria*, *Solen gladiolus*, *Nassa reticosa*, *Pecten opercularis*, *Cardium edule*, *Mytilus edulis*, *Murex erinaceus*, *Pectunculus glycimeris*, *Trophon antiquum*, *Buccinum striatum*, and *Dentalium entalis* are among the typical species. These indicate a more temperate climate than those of the Coralline Crag. Remains of *Elephas antiquus*, *Halitherium Canhami*, *Hyœna antiqua*, *Rhinoceros Schleiermacheri*, *Mastodon arvernensis* (a species of horse (*Hipparion*), *Canis lupus*, and *Felis pardoïdes* are among the mammals which have been unearthed. The best localities are in the cliff-sections of Felixstowe and Bawdsey, and in the valleys of the rivers Orwell and Deben.

* These its first describer thought to be corals; hence the name of "Coralline Crag."

† For a large number of these species see the author's forthcoming volume on "Marine Shells," in this series.

Professor Prestwich remarks about the Coralline and Red Crag, that "whilst the Coralline Crag consists essentially of light-coloured calcareous beds, with an admixture of siliceous sand, the Red Crag consists of a base of siliceous sands, with more or less of the peroxide of iron, and a few thin seams of clay. They form such an extremely variable series that I have failed to observe any definite order of succession in the various beds of the lower series, or to recognise the 'beach-stages' of Mr. S. V. Wood, junr. I would divide them into two groups only; the lower one characterized by the prevalence of oblique lamination, without permanent or definite order of succession in the beds, and the upper by more persistent horizontal bedding. Shells abound in the lower, and are rarer in the upper division."

The *Norwich*, or *Mammaliferous*, *Crag* can be well worked in the pits at Thorpe and Bramerton near Norwich, and at Beccles.* Here it consists of loose sand, gravels, and loam, containing both fluviatile and marine species, which show that it was deposited in an estuary. For this reason, it is sometimes called the "Fluvio-Marine Crag." The other name of "Mammaliferous Crag" has been given, on account of the large number of mammal remains that have been taken from it. These are, among others, *Bison priscus*, *Mastodon arvernensis* (only the teeth of this species have been found), *Elephas antiquus*, *E. primigenius*, *E. meridionalis*, *Hippopotamus major*, *Ursus arvernensis*, and *Trogontherium Cuvieri*.

The characteristic Mollusca are *Turritella communis*, *Littorina littorea*, *Cardium edule*, *Hydrobia ventrosa*, *Paludina media*, *Mytilus edulis*, and *Nucula Cobboldiæ*. "One interesting feature," says Geikie," is the decided mixture of northern species of shells, such as *Rhynchonella psittacea*, *Scalaria greenlandica*, *Panopæa norvegica*, and *Astarte borealis*. These may be regarded as the forerunners of the great invasion of Arctic plants and animals which, in the beginning of the Quaternary ages, came southward into Europe, together with the severe climate of the north."

The *Chillesford Beds*, found near Chillesford in Suffolk, is a marine deposit of sands and clays from ten to twenty feet in thickness. Two-thirds of the shells found in it are identical

* Postwick, Whitlington, Brundall, Wroxham, Belaugh, Coltishall, and Ditchingham are also good localities.

with species still living in the cold seas of Greenland and Spitzbergen. The characteristic fossils are *Mya truncata*, *Saxicava rugosa*, *Scalaria greenlandica*, *Natica catena*, *Trophon antiquum*, *Purpura lapillus*, *Panopæa norvegica*, *Kellia ambigua*, *Mactra elliptica*, *Cyprina islandica*, *Astarte borealis*, *Nucula Cobboldiæ*, *Tellina lata*, and *T. obliqua*.

The *Forest Bed Group* is a pre-glacial deposit found resting on the Norwich Crag along the north-east coast of Norfolk. They are a series of peat layers with the remains of a former land surface; the fauna is both estuarine and marine. The shells include many living to-day; such as *Pisidum amnicum*, *Unio pictorum*, *Paludina vivipara*, *Planorbis fontanus*, *Limnæa stagnalis*, *Succinea putris*, *Helix arbustorum*, *Trophon antiquum*, and *Nucula Cobboldiæ*. The remains of *Elephas antiquus* are very abundant; with two species of *Ursus*, *Martes sylvatica*, *Sus scrofa*, two species of horse and rhinoceros, ten species of *Cervus*, *Bos primigenius*, *Mus sylvaticus*, *Arvicola nivalis*, *A. gregalis*, *A. intermedia*, *Castor Europæus*, *Elephas meridionalis*, *E. primigenius*, *Monodon monoceros*, and *Delphinus delphis*. The fish, amphibians, and reptiles are nearly all identical with those living at the present day. The bog-bean, oak, hazel, hornwort, yellow pond-lily, and white water-lily flourished as they do to-day.

Some deep orange-coloured sands, called the "Bure Valley Beds," occur near Halesworth, Henham, Weyburn, Runton, Rackheath, Wroxham, and Southwold. They contain *Tellina Balthica*, *T. obliqua*, *Cardium edule*, *Littorina littorea*, *Cyprina islandica* and *Leda oblongoides*.

CHAPTER V.

THE LIFE OF THE POST-TERTIARY OR QUATERNARY EPOCH.

We purposely consider this epoch apart from the Cainozoic, although in some palæontological works it is included with it as a period. During the later Tertiary Ages the climate, with the fauna and flora, had been gradually getting more and more Arctic; it has now become entirely glacial. Probably about 80,000 years ago no less than 7,840,000 square miles of the land-surface of the northern hemisphere was covered with ice which had, probably, lasted for 160,000 years. "The whole northern hemisphere," says Louis Agassiz, "became enveloped in a shroud of ice and snow to an enormous depth (which, as in the case of Britain, attained to something like 4,000 feet). The surface of Europe—adorned before by a tropical vegetation, and inhabited by troops of large elephants, enormous hippopotami, and gigantic carnivora—was suddenly buried under a vast mantle of ice, covering alike plains, lakes, seas, and plateaux. Upon the life and movement of a powerful creation fell the silence of death. Springs paused; rivers ceased to flow; the rays of the sun rising upon this frozen shore (if, indeed, it was reached by them) were only met by the breath of winter from the north and the thunders of the crevasses as they opened across the surface of this icy sea."

The student who has read, as recommended in the preface, Professor Geikie's "Elementary Lessons in Physical Geography," already knows something about glaciers and the way in which they groove the rocks they pass over: he also knows something about the terminal and lateral moraines, and what the French have called *moraine profonde* and *roches moutonnées*. It is exactly by the presence of these perched blocks, moraines, and striated rock-surfaces, that, apart from all consideration of "life," we have indubitable evidence of the existence in England and elsewhere of the glacial period. After the glacial

period was at its maximum, the land subsided beneath the sea, but to rise again, and again to become covered with ice; the eastern part of the Midland counties was 500 feet under the sea, and Snowdon formed an island about 1,000 feet above sea-level. What the cause of the glacial period was, it is hard to state, and at least seven theories have been put forward to account for it. Perhaps the most feasible one is, that it was due in part (if not entirely) to changes in the distribution of land and sea, and therefore to a change in the flow of the then existing oceanic currents. The ocean is the great equalizer of

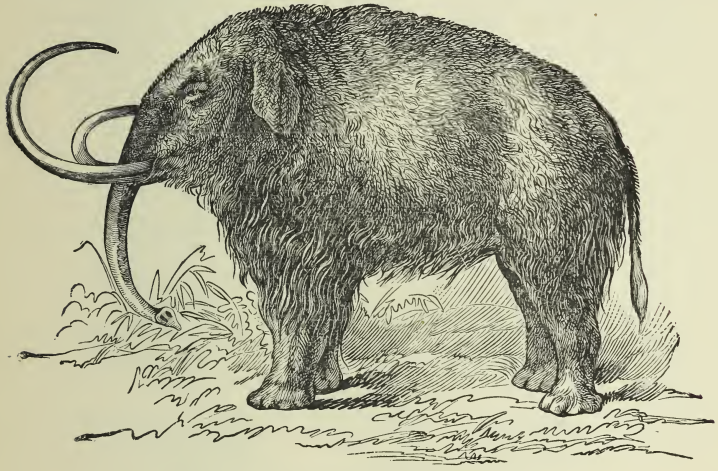

Fig. 21.—The Mammoth (*Elephas primigenius*).

temperature, acting—to use the words of Sir William Dawson, in his Presidential Address to the British Association in 1886—"by its great capacity for heat, and by its cooling and radiating power when passing from the solid to the liquid and gaseous states, and the reverse. It also acts by its mobility, its currents serving to convey heat to great distances, or to cool the air by the movement of cold icy waters. The land, on the other hand, cools or warms rapidly, and can transmit its influence to a distance only by the winds; and the influence so transmitted is rather in the nature of a disturbing than of an equalizing cause. It follows that any change in the

distribution of land and water must affect climate, more especially if it changes the character or course of the ocean currents."

Under the name "Boulder Clay," or "Till," is included unstratified deposits of stiff clays or loams containing angular blocks of stone, which frequently exhibit striation, and which have been moved from their parent site. "Brick Clays" are mud deposits containing Arctic shells, formed from the mud which was deposited by the glacier-stream, as it flowed into a fjord. The name of "Stratified Drift" is given to a stratified series of clays, sands, and gravels containing Arctic shells, and also sometimes erratic blocks. Professor Geikie thus tabu-

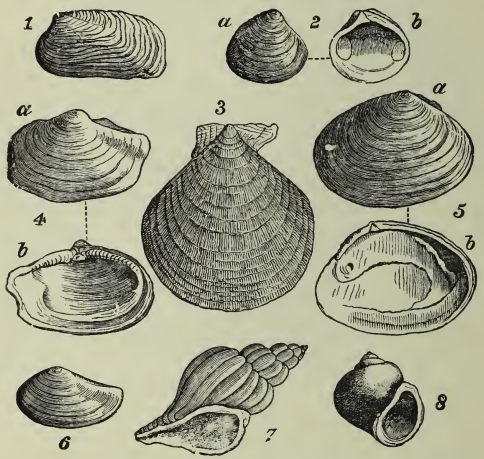

FIG. 22.—Arctic shells found in the Scottish Glacial Clays.

1, *Saxicava rugosa*; 2, *Astarte borealis* (*a*, Exterior of valve; *b*, Interior of valve); 3, *Pecten Islandicus*; 4, *Leda truncata* (*a*, Exterior of left valve; *b*, Interior of left valve); 5, *Tellina calcarea* (*a*, Exterior of left valve; *b*, Interior of left valve); 6, *Leda lanceolata*; 7, *Trophon clathratum*; 8, *Natica clausa*.

lates the glacial succession, in descending order, of Scotland and the greater part of England and Ireland—

SCOTLAND.

a. Last traces of glaciers, small moraines at the foot of corries among the higher mountain groups. The glaciers, no doubt, lingered longest among the higher mountains of the

north-west (Highlands, Galloway, Lead Hills, Hartfell and Loch Skene, Arran, Mull, Skye, Harris, Orkney, Shetland).

b. Marine terraces (50 feet and higher). Clay-beds of the Arctic sea-bottom (Clyde Beds) containing northern molluscs. The marine terraces prove a submergence of at least 100 feet beneath the present level of the land. How much beyond that limit the submergence reached has still to be determined.

c. Large moraines, showing that the glaciers of the second period descended to the line of the present sea-level in the north-west of Scotland.

d. Erratic blocks, chiefly transported by the first ice-sheet, but partly also by the later glaciers, and partly by floating ice during the period of submergence.

e. Sands and gravels—Kame or Esker series, sometimes containing terrestrial organisms, sometimes marine shells.

f. Upper boulder-clays—rudely stratified clays with sands and gravels.

g. Till or lower boulder clay (bottom moraine of the ice-sheet)—a stiff, stony, unstratified clay, varying up to 100 feet or more in thickness. It contains intercalated bands of fine sand, finely laminated clays, layers of peat and terrestrial vegetation, and bones of mammoth and reindeer (inter-glacial beds), also in some places fragmentary or entire Arctic and boreal marine shells. The boulder-clay spreads over the lower grounds, often taking the form of parallel ridges or drums.

h. Ice-worn rock surfaces.

ENGLAND AND IRELAND.

4. Moraines (North Wales, Lake District, etc.) and raised beaches.

3. Upper boulder-clay—a stiff stony clay or loam with ice-worn stones and intercalations of sand, gravel, or silt (chalky boulder-clay of East Anglia). It occasionally contains marine shells.

2. Middle sands and gravels, containing marine shells. Near Yarmouth, the middle glacial beds have yielded shells of a more southern aspect. At Macclesfield (1,200 feet above the sea) there have been found *Cytherea chione*, *Cardium rusticum*, *Arca lactea*, *Tellina balthica*, *Cyprina islandica*, *Astarte arctica*, and other shells now living in the seas round Britain, but indicating perhaps by their grouping a rather

colder climate than the present. In Ireland, marine shells of living British species occur at heights of 1,300 feet above the sea.

1. Lower boulder-clay—a stiff clayey deposit stock full of ice-worn blocks, and equivalent to the Till of Scotland. On the east coast of England (Holderness, Lincoln, and Norfolk), it contains fragments of Scandinavian rocks; in particular, gneiss, mica-schist, quartzite, granite, syenite, rhomben-porphyr; also pieces of red and black flint, probably from Denmark, and of carboniferous limestone and sandstone, which have doubtless travelled from the north. Along the Norfolk cliffs it presents stratified intercalations of gravel and sand, which have been extraordinarily contorted. As in Scot-

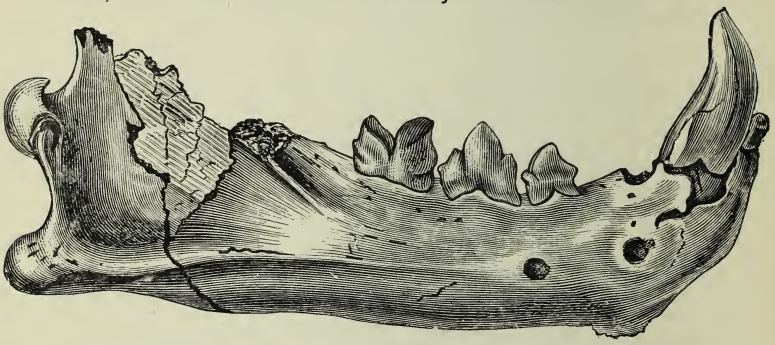

FIG. 23.—One half of the lower jaw of the Cave Lion (*Felis spelæa*), partially broken. From one of the caves of the Mendip Hills. (*After Boyd Dawkins and Sandford.*)

land, the true lower boulder-clay in the north of England and Ireland is often arranged in parallel ridges or drums in the prevalent line of ice-movement."

Before closing our short *résumé* of the main facts of palæontology as studied in the light of British fossils, there remain a few words to be said about the principal ossiferous caves which have been explored in this country, as those of Kirkdale near Kirby Moorside in Yorkshire, Kent's Cavern near Torquay, those of Hutton in the Mendip Hills, and the Oreston Caves near Plymouth. All these caves are found in stratified limestone; their excavation is probably due to water charged with carbonic dioxide which has percolated through the joints and fissures of the rock and dissolved out the lime.

Their contents are remains of mammals; they were feeding caves, and contain bones which have been gnawed.

Kirkdale Cave, perhaps the most remarkable bone-bearing cave in England, is entered on the side of a narrow valley, near Kirby Moorside in Yorkshire. No less than the remains

FIG. 24.—The Irish Elk.

of three hundred hyænas have been found in it, associated with the bones of tigers, lions, wolves, foxes, weasels, elephants, hippopotami, horses, rhinoceroses, oxen, deer, hares, rabbits, mice, water-rats, ravens, pigeons, larks, and ducks. In *Kent's Cavern*, tools of Primitive Man have been found, with hyæna bones; in the *Oreston Caves*, teeth and bones of rhinoceroses

and other animals. The *Mendip Caves* have yielded bones of oxen, bears, hyænas, deer, horses, rhinoceroses, and elephants.

River gravels also form good hunting-grounds for fossils of the Quaternary epoch. In those of the Thames valley, land and river shells have been found, with bones of *Equus caballus*, *Cervus tarandus*, *Elephas primigenius*, *Elephas antiquus*, *Rhinoceros tichorhinus*, *Bison priscus*, *Ursus arctos*, and *Canis lupus*, and flint implements of human origin. At Crayford, Ilford, Grays, and Erith, the remains of *Rhinoceros megarhinus*, *R. leptorhinus*, *R. tichorhinus*, and the shells *Unio littoralis*, *Cyrena fluminalis*, *Hydrobra marginata*, *Valvata piscinalis* var. *antiqua*, and *Paludina contecta* may be obtained.

Alluvial deposits should also be examined; these often yield the remains of the mammoth, northern rhinoceros, reindeer, grizzly bear, brown bear, Irish elk, lion, hyæna, and hippopotamus, with the stone weapons of Primitive Man.

The First Man, rude, uncultivated, untutored, has appeared in England. Him we leave to the archæologist and the ethnologist. His probable birthplace was in Asia, on the great plain or plateau which extends from Persia across Thibet and Siberia to Manchuria. Andrew Lang sings about him :—

"He lived in a cave by the seas,
He lived upon oysters and foes,
But his list of forbidden degrees
An extensive morality shows;
Geological evidence goes
To prove he had never a pan,
But he shaved with a shell when he chose,
'Twas the manner of Primitive Man!

He worshipped the rain and the breeze,
He worshipped the river that flows,
And the dawn, and the moon, and the trees,
And bogies, and serpents, and crows;
He buried his dead with their toes
Tucked up, an original plan,
Till their knees came right under their nose,
'Twas the manner of Primitive Man!

His communal wives, at his ease,
He would curb with occasional blows;
Or his state had a queen, like the bees
(As another philosopher trows):
When he spoke it was never in prose,
But he sang in a strain that would scan,
For (to doubt it, perchance, were morose)
'Twas the manner of Primitive Man!"

CHAPTER VI.

COLLECTING FOSSILS, AND ARRANGING THEM IN THE COLLECTION. LIST OF BOOKS LIKELY TO BE OF SERVICE TO THE STUDENT.

MAKE at first your own locality—the locality in which you reside—your home for collecting fossils. Learn all you can of the fossils in the rocks near you, before departing to "fresh fields and pastures new." It is as true to-day "that that district produces the greatest variety which is the most examined," as it was over one hundred years ago, when Gilbert White penned these memorable (and now classic) words to Thomas Pennant (the zoologist), no less in zoology and botany than in geology and palæontology. Even in a district which is comparatively unfertile as regards its fossils, there is generally somewhere to be found exposed a series of strata which will yield a basketful.

The implements, etc., useful to the fossil collector are, a small pick, one or two geological hammers of different weights (one of 2 lbs. weight, for working in the field, and one of 6 oz. weight, for trimming the fossils at home, are useful), several chisels of different sizes, a trowel for scooping up shale, a pair of pincers for trimming friable specimens, a canvas collecting bag, pill-boxes (filled with sawdust) for carrying the delicate and smaller specimens home, plenty of old newspapers to wrap the larger fossils in, a thin solution of fish-glue for mending broken specimens, and a note-book in which to write the various data as to locality, bed, etc., of each fossil you collect.

And in working forget not the following rules in any one particular :—

1. Keep the fossils from separate localities, or from separate beds in the same quarry, *distinct*, and make notes concerning the location of each fossil (to which a numbered label is to be added on the spot) against a corresponding index in the note-book. *Make these notes, without fail, on the spot, and leave nothing to memory.*

2. Note the posture of the fossils before extracting.

3. Work the beds in a quarry or section from below upwards.

4. Do not forget the weathered *débris* at the bottom of the section, or any masses of shale, etc., which have been left by the quarrymen. Work these systematically from below upwards.

5. Become friends of the quarrymen, and offer them remuneration for saving you any good specimens.

6. Where a special fossiliferous zone occurs, work that first.

7. In working beds which show cleavage, break the fragments across the cleavage in order to find fossils in the planes of bedding.

8. In chiselling any soft rock, keep the chisel directed from the fossil, and take a large quantity of the surrounding rock with it.

9. Roughly trim in the field only; do your finer trimming at home.

10. Throw nothing away without subjecting it to a minute examination.

11. Be careful of the more fragile specimens. Place them in separate boxes filled with sawdust.

For the very minute fossils, such as sponge-spicules, etc., small portions of shale must be removed from the weathered surface of the rock by the trowel, and taken home for further examination. This examination consists in carefully drying the shale (if wet), and then placing it in water until it crumbles down. The muddy portion of the water is poured off, after the heavier matter has sunk to the bottom; a process which is repeated again and again until the water is no longer muddy but tolerably clear. The residue is now boiled over a brisk fire for half an hour, and the muddy water obtained by this boiling is poured off, as often as is needed, taking care of the larger masses. When the boiling water becomes no longer muddy, the residuum can be poured on to a slate and searched with a lens for fossils. In working glacial and other clays for the same class of fossils it is best to first dry the clay in an oven, and then add water so as to bring it in a condition of fine mud; allow time for any larger particles to settle, and then remove the mud suspended in the water by decanting. Add fresh water as often as needed, and afterwards examine the residue as before.

The fossils obtained from loose sands and gravels require to

be soaked in a hot solution of gum or gelatine. Mr. Davies has described the process as follows, and we cannot do better than repeat his words. "The substances generally used are glue or gelatine. For the bones of the larger mammalia, there is nothing better than the best glue; whilst for the more delicate bones of the smaller mammals, birds and fishes, gelatine is the best, being purer, dissolving more easily, and imparting little, if any, colour to the fossil. The consistency of these substances when used will have to be varied according to the structure of the bones, and this must be left to the judgment of the operator. As a general rule, however, all bones which have a coarse cellular structure require the glue solution to be of a consistency which will form a stiff jelly when cold; whilst for bones of a compact structure a thinner solution will suffice. If the solution is too thick it clogs the absorbing power at the surface, and prevents it penetrating to all parts of the bone. The fossils should be thoroughly dried and cleaned from as much of the matrix as can be removed with safety; and, if it can be managed, warmed before being placed in the solution. When the glue is all dissolved, and the liquid nearly at boiling point (ebullition should be avoided, if possible), it is ready for the immersion of the fossils, and they should remain in it as long as air-bubbles rise to the surface; when these cease they will be sufficiently soaked. When taken out they should not be drained, but laid in a position to retain as much as possible of the imbibed solution until they are cold, when the glue will have set. Their position must then be shifted, to prevent their adhering to the board on which they are laid. Any glue that may have drained from them may be then removed with a wet sponge. The vessels required are of the simplest kind: the ordinary saucepan, or better still, a large-sized fish-kettle with its strainer. But, whatever the vessel used, a strainer of some kind, on which to place the bones for immersion or withdrawal, is indispensable. . . . For long limb-bones strong enough to bear their own weight when saturated, it is only necessary to place one end in the vessel and ladle the solution over the other end for a short time, and then reverse their position. But for bones which will not bear such treatment, the only plan is to fix them securely to a board, and place them in a slanting position in the solution, and well saturate them with it by ladling. . . . Occasionally fossils are found which are

either too large or too friable to be placed in the solution; for these a different method must be adopted to preserve them entire. Cover the fossil with thin paper, over which—on the sides and underneath, if possible—put a coating of plaster of Paris just thick and strong enough to keep together; when firmly set, gently pour the solution boiling hot over the fossil as long as it continues to absorb, to assist which it may be necessary to remove in a few places some of the surface bone, which can be carefully replaced; in two or three days the plaster may be partly removed by sawing, and in small pieces, taking care not to injure the fossil by jarring it; the paper will prevent the plaster adhering to it. But this process is never so effective as submersion in the solution, and may require to be repeated.

"For cementing large pieces of bone together, Sir Antonio Brady recommends strong glue mixed with a small portion of fresh-burnt plaster of Paris; but for smaller bones, shellac dissolved in naphtha is said to answer best." Specimens from the Gault beds, which are liable to crumble, should be soaked in gum arabic or tragacanth mucilage. Chalk specimens should be soaked in water for several weeks—the water should be changed twice a week. The other kinds of fossils, being more obdurate, need nothing but careful trimming with the small hammer or pincers.

A cabinet is not needed by the student, and it would be well that he spend his money in getting together books on the fossils of the various periods. The smaller specimens are best kept in pill-boxes. The larger ones may be kept in cardboard trays or wooden boxes arranged either in a zoological and botanical series, or according to the strata in which they have been found. But place an index number to each, corresponding to a number in your note-book, as to locality, bed, position, etc. The label may also contain the name (if known); and in naming it is always well to seek the aid of a good and well-known palæontologist. The following books, however, will help the collector in naming his fossils:—

Phillips' "Manual of Geology," vol. ii. By Etheridge.
Geikie's "Text-book of Geology."
Jukes-Browne's "Historical Geology."
Mantell's "Medals of Creation."
Owen's "Palæontology."
Nicholson's "Manual of Palæontology."

Baily's "Figures of Characteristic British Fossils."

Bronn's "Palæontological Index."

Morris's "Catalogue of British Fossils."

Nicholson's "Monograph of the British Graptolidæ."

Traquair's "Monograph of the Ganoid Fishes of the British Carboniferous Formation" (*Palæontographical Society*, 1877).

Miall's "Sirenoid and Crossopterygian Ganoids" (*Palæontographical Society*, 1878).

Newberry's "Carboniferous and Devonian Fishes" (*Palæontology of Ohio*, 1873 and 1875).

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CHAPTER VII.

GLOSSARY OF TERMS.

Actinolite.—A fibrous variety of Hornblende. (Greek, *actinotos*, radiated.)

Agglomerate.—An assemblage of angular blocks embedded in a matrix of finer materials.

Alabaster.—A compact variety of gypsum ($CaSO_4\ 2OH_2$).

Alluvium.—The muddy soil at the bottom of a river valley, composed of rain-wash from the hills and of flood deposits.

Amphibole.—A synonym of hornblende.

Amygdaloidal.—A term applied to a rock which was first vesicular, but in which the vesicles were afterwards filled with some mineral, as calcite or quartz.

Anamesite.—An intermediate variety between speckled dolerite and black basalt.

Andalusite.—A silicate of aluminium, with smaller quantities of the silicates of potassium, magnesium, and iron. (From Andalusia in Spain.)

Anthracite.—A hard, heavy, and glossy variety of coal; sometimes called stone-coal. (Greek, *anthrax*, fuel.)

Anticlinal.—A term applied to the curves of strata when they bend upwards into an arched- or saddle-form.

Apatite.—A crystallized condition of calcic phosphate ($Ca_3\ PO_4$); the crystals are six-sided prisms belonging to the hexagonal system. (Greek. *apatao*, to deceive.)

Aphanite.—A term used for the compact dolerites.

Aplite.—A variety of granite characterized by the small amount of mica it contains.

Aragonite.—Crystals of calcite ($CaCO_3$) of a rhombic character. (From Aragon in Spain.)

Argillite.—A coarse-grained metamorphic rock produced by the partial fusion of clays.

Astrakanite.—A compound of magnesium sulphate and sodium sulphate leposited in winter time in the salt lakes near the mouth of the Volga.

Augite.—Black, white, or green crystals of the silicates of magnesium and calcium, with more or less of the silicates of iron and manganese; the crystals are short, stout prisms belonging to the monoclinic system. (Greek, *augē*, lustre.)

Barbadoes Earth.—A name given to a siliceous deposit in Barbadoes composed of the skeletons of Polycistina. (The *Polycistinæ* belong to the sub-kingdom, *Protozoa*.)

Basalt.—A black-coloured lava composed of augite and a variety of felspar, and breaking with a shell-like or conchoidal fracture.

Basset.—A synonym for outcrop.

Bind, or Blue-bind.—The quarrymen's name for shale.

Boulder.—Large water-worn stones found in the boulder clay.

Boulder Clay.—Moraine matter from old glaciers. Well seen in the valleys of Snowdon and Cumberland.

Breccia.—Angular fragments of rocks cemented together.

Calcareous.—Composed of lime.

Calcite, or Calc-spar.—Rhombohedral crystals of calcium carbonate ($CaCO_3$). It dissolves with effervescence in hydrochloric acid, and is easily scratched with a knife. (Latin, *calx*, lime.)

Chalk.—A carbonate of calcium ($CaCO_3$) composed in the main of remains of Foraminifera.

Chert.—A limestone containing an abundance of silica. A kind of flint breaking with a flat fracture.

Chlorite.—A hydrated magnesium and iron silicate with some sesquioxide of aluminium. It has the following average percentage composition:—

Silica	30 to 34
Magnesia	32 to 37
Alumina	10 to 20
Water	12 to 13

And occurs either in leek-green granules or as fibrous crystals which radiate from a common centre. (Greek, *chloros*, green.)

Clay.—A compound chiefly composed of aluminium silicate and water (Al_2O_3, $2SiO_2$, $2OH_2$) produced by the action of water and other natural agencies upon rocks, owing to the decomposition of felspar and other aluminous silicates. It is impervious to water.

Cleavage.—A name given to the tendency of some rocks to split into layers more or less perpendicular to the original plane of deposition.

Clunch.—A popular name for a tough, sandy marl.

Columnar.—Arranged like columns.

Concretion.—A term applied to the separate nodules frequently found in stratified deposits.

Conglomerate, or **Pudding-stone.**—A name applied to a rock composed of rounded pebbles cemented together into a mass by carbonate of calcium, silica, or oxide of iron.

Coprolites.—Nodules found in clays and calcareous shales composed of phosphate and carbonate of calcium, with usually a large quantity of iron; probably the internal casts of the intestinal canal of saurians, fish, etc.

Cretaceous.—Chalky.

Débris.—A term applied to the loose material arising from the crumbling and breaking up of rocks by erosion and disintegration.

Denudation.—The laying bare of rock surfaces by the removal of the overlying beds. The removal of the overlying beds is sometimes called DETRITION.

Detritus.—A synonym of *débris*.

Diabase.—An eruptive rock composed of felspar, augite, magnetite, apatite, generally viridite, and sometimes olivine.

Diorite.—A crystalline rock of a granular texture composed of felspar and hornblende with sometimes mica, augite, magnetite, and apatite.

Dip.—The angle of the inclination of strata to the plane of the horizon. It is usually measured by an instrument called the *clinometer*, and, of course, only occurs in those rocks which have been moved out of their original horizontal position.

Dolerite.—A speckled white and black rock composed of felspar and augite.

Dolomite.—A mixture of calcium carbonate and magnesium carbonate, generally known as magnesian limestone. (After Dolomieu, a geologist.)

Dyke.—A vertical wall of igneous rock, which has been forced in a molten state into a fissure in the earth's crust, and there solidified.

Eclogite.—A rock consisting of red garnets and hornblende.

Erosion.—The abrasion of a land surface by natural agents.

Escarpment.—A line of cliff; the outcrop of a hard bed owing to the wearing away of softer overlying materials.

Euphotide.—An altered gabbro in which the felspar has been converted into a hard white material somewhat allied to saussurite.

False-bedding.—Irregular bedding, indicating some change in direction and velocity of the currents by which it was deposited.

Fault.—A dislocation by which displacement of strata has taken place.

Felsite, or **Felstone.**—A dull green or purplish coarse-grained rock consisting of felspar and quartz.

Felspar.—A mineral, varying in colour from white to light-red, composed of the oxides of aluminium, silicon, and potassium chemically united. When crystallized it occurs as oblique rhombic prisms; and instead of potash sometimes contains soda (Na_2O) or lime (CaO). It is a silicate of aluminium and potassium. Its composition may be represented by the formula Al_2O_3, $3SiO_2+K_2O$, $3SiO_2$.

Fire-clay.—A siliceous clay composed of pure sand (often 50 to 60 per cent) with silicate of aluminium mixed.

Firestone.—A calcareous sandstone in which the siliceous matter is predominant.

Flagstone.—An argillaceous sandstone easily splitting along the planes of bedding.

Flint.—A dull-looking variety of silica which breaks with a conchoidal fracture.

Fluorspar.—A fluoride of calcium (CaF_2) crystallizing in cubes belonging to the isometric system. Synonyms—Blue John, Derbyshire Spar. (From Latin, *fluo*, to flow, as it is used as a flux in working some ores.)

Foliation.—A term proposed by Sedgwick and applied to rocks (as schists) which separate "into layers of a different mineral composition."

Fossils.—Remains of animals or plants which have been buried in the earth by any agency other than that of man.

Fuller's Earth.—A soft clay, greenish or bluish in colour, composed of 20 per cent. of alumina, 50 per cent. of silica, 25 per cent. of water, and a little iron oxide.

Gabbro.—A granular rock, common in dykes and closely allied to dolerite, composed of labradorite or saussurite and diallage or hypersthene.

Garnet.—A red, brown, or black rock common in metamorphic and intrusive rocks and containing from 35 to 40 per cent. of silica; it is a silicate of aluminium with a silicate of either iron, calcium, magnesium, or manganese. Generally the crystals are rhombic dodecahedrons; they always belong to the cubic system. (From the Latin, *granatus*, grain-like.)

Glauconite.—A greenish, yellowish, or greyish rock composed of silicate of iron and potassium. It is found very frequently as small grains in greensand, chloritic marl, and in the lower parts of the chalk marl. (Greek, *glaukos*, sea-green.)

Gneiss.—A rock with the same composition as granite (which see), but the minerals are arranged in layers (*foliated*).

Granite.—A rock composed of a mixture of quartz, felspar, and mica, the felspar being in the greatest quantity.

Graphite.—A form of carbon ; also called plumbago and black-lead. It is found in irregular masses and beds in gneiss, granite, mica-schist, and limestones. (Greek, *grapho*, I write.)

Greenstone.—A synonym of Diorite ; it consists of triclinic felspar and hornblende.

Gypsum.—A mineral composed of calcium sulphate ($CaSO_4+2H_2O$). It is easily cut with a knife, does not effervesce with acids, and can be split into thin plates which are brittle in one direction, and flexible in another. (From *gupsos*, the old name for the mineral, or from the Greek *ge*, the earth, amd *epseo*, I cook.)

Hæmatite.—A steel-grey form of iron with a sub-conchoidal fracture and giving a reddish-brown or cherry red streak. It frequently occurs in rhombohedrons or thin plates, and is found in some parts of Cornwall, Devonshire, Cumberland, Somersetshire, and in the carboniferous limestone of North Lancashire. (Greek, *haima*, blood.)

Hardness.—This term is applied to that property of bodies in virtue of which they resist being scratched by others. The following are wha. are known as standard examples for hardness-tests (Moh's scale)—

1. Talc .....common foliated variety.
2. Rock salt .....or gypsum.
3. Calc-spar .....transparent variety.
4. Fluor-spar.....crystallized variety.
5. Apatite ..... transparent crystallized variety.
6. Felspar .....(orthoclase) cleavable variety.
7. Quartz .....transparent variety.
8. Topaz .....transparent crystal.
9. Sapphire.....cleavable variety, or corundum.
10. Diamond.

Thus, if the mineral will scratch fluor-spar, but not apatite, its hardness is expressed by using a decimal fraction between the whole numbers 4 and 5, as 4·5, 4·75, etc.

Hornblende.—A silicate of the protoxide of iron, magnesium, aluminium, calcium, and protoxide of manganese with a small quantity of hydrofluoric acid and water. Its crystals belong to the monoclinic system and are of a blackish colour, giving a pale streak. (*Horn*, from its toughness, and blind (*blende*) from its being useless as an ore, or blind.)

Labradorite.—A form of felspar, consisting of a silicate of aluminium, *calcium*, and sodium. Its colours vary through grey to reddish or greenish, and, when crystallized, it occurs as doubly oblique rhomboidal prisms and exhibits a fine display of colours. Al_2O_3, $2SiO_2+RO.\ SiO_2$.

Leucite.—Often called white garnet, is a silicate of aluminium and potassium ($Al_2O_3.\ 3SiO_2+K_2O.SiO_2$), crystallizing in white or grey

tetragonal pyramids, and breaking with a shell-like fracture. (Greek, *leukos*, white.)

Lignite.—Coal in an early stage of formation. (Latin, *lignum*, wood.)

Limestone.—A general term for calcium carbonate when it occurs in beds.

Limonite.—An iron-ore of a brown or yellow colour, giving a yellowish-brown streak. (Greek, *leimōn*, a meadow.)

Magnetite.—Magnetic iron-ore with a formula of Fe_3O_4, generally found in metamorphic rocks. It is iron-black in colour, has a metallic lustre, gives a black streak, and breaks with a sub-conchoidal fracture.

Marcasite.—A form of pyrites, but paler and crystallizing in the rhombic system.

Marl.—A soft and friable mixture of clay and calcareous matter.

Mica.—A common mineral, of varying colour, found commonly in eruptive and metamorphic rocks as gneiss, granite, and mica-slate, and in some sedimentary rocks as grits, shales, and micaceous sandstones. Its percentage composition is—

Silica	46·3
Alumina	36·8
Potash	9·2
Peroxide of iron . .	4·5
Fluoric acid . . .	0·7
Water	1·8

and its chemical formula $3Al_2O_3.SiO_2+K_2O.3SiO_2$ or $3Al_2O_3$, SiO_2+KO, $3SiO_2$. Its lustre is pearly and it crystallizes in six-sided tables. Another name for it is Muscovite.

Oligoclase.—A soda felspar, commonly found massive, but sometimes in a crystallized state as doubly oblique rhomboidal prisms. Its formula is $2Al_2O_3.SiO_2 + 2(NaO.CaO)\ 3SiO_2$, or $2Al_2O_3.3SiO_2 + 2(Na_2O.CaO)\ 3SiO_2$. (Greek, *oligos*, little, and *clao*, I cleave.)

Olivine.—A common mineral, of a greenish, brownish colour, occurring in rounded grains in basalt and other igneous rocks. It is a silicate of magnesium and protoxide of iron.

Orthoclase.—A potash-felspar with a formula of $Al_2O_3.3SiO_2+K_2O.3SiO_2$. It crystallizes in oblique rhombic or in thick oblique rectangular prisms. (Greek, *orthos*, straight, and *clao*, I cleave.)

Pegmatite.—A form of granite in which the mica is almost absent.

Quartz.—A crystallized silica (SiO_2), occurring as six-sided prisms, terminated by six-sided pyramids. When pure they are colourless, but are often coloured by impurities. Another name is Bristol diamond.

Quartzite.—A sandstone in which the grains of sand have run together owing to partial fusion.

Schists.—Foliated rocks, splitting in thin laminæ of different mineral characters. According to the preponderance of any one mineral, we have the names *mica-schist*, *hornblende-schist*, *quartz-schist*, etc.

Selenite.—A crystallized, transparent variety of gypsum. (Greek, *selene*, the moon, owing to its pearly lustre.)

Septaria.—Concretions of calcium carbonate, occurring in clays.

Serpentine.—An altered magnesian rock found in quantity in the Lizard district of Cornwall, Anglesea, and other localities. Its chemical formula is $3MgO.2SiO_2+2H_2O$.

Shale.—Hardened clay or mud which splits into laminæ parallel to the stratification.

Sinter.—A porous variety of silica occurring round geysers and hot springs.

Strike.—The line running at right angles to the plane of the dip.

Syenite.—A variety of granite in which the mica is replaced by hornblende.

Synclinal.—A term applied to the curves of strata when they dip towards an axis which forms a trough or basin.

Trachyte.—A grey lava, feeling rough and prickly to the fingers, composed of potash felspar and other silicates.

Trap.—A general name for those igneous rocks which have been solidified under slight pressure, as water.

Travertine.—A light and porous deposit of calcium carbonate by springs.

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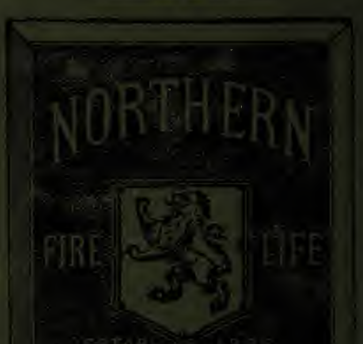

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